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Station.

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LONG ASHTON, BRISTOL,

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INTRODUCTION.

In reporting on the work of the Institute for 1923 it was pointed out that for the first time since the outbreak of the war it had been possible to proceed under relatively stable and settled conditions. While in most respects these conditions have been maintained during 1924 the abnormal number of staff changes which have occurred has made continuity in certain directions of research difficult and in a few instances a definite break—temporary only, it is hoped—has resulted. The development of the work generally is taking a natural course, limited only in its increase by the extent of staff and money available. Each of the major problems upon which the Station is engaged is constantly opening up fresh avenues which require to be explored and the fact must be faced that the rate of progress in future will undoubtedly be dominantly determined by the resources at disposal. Results of practical significance are already foreshadowed in many lines of work and it needs only the necessary means to secure them.

The additions to the Station in the shape of buildings, land and equipment referred to in the two last Annual Reports, the cost of which has been largely met by a capital grant from the Ministry of Agriculture, are now practically complete. Further information on these will be found below in the sections on Land and Buildings.

Staff.—The post of Plant Physiologist left vacant by the departure of Mr. F. Summers has been filled by the appointment of Mr. C. E. T. Mann, M.Sc., who was previously on the staff of the Botanical Department of University College, Reading. The Institute is greatly indebted to Professor V. H. Blackman, M.A., F.R.S., for advice and assistance which he has very kindly undertaken in connection with the work on this subject.

Mr. E. Ballard, B.A., who was appointed as Adviser in Economic Entomology as recently as the last academic year, accepted the offer of an important entomological appointment under the Cotton Research Association in Australia and left the service of the Station at the end of January, 1924. For the summer months the duties of this post were temporarily undertaken by Mr. L. N. Staniland, A.R.C.S., whose services were secured for that period by arrangement with Professor H. M. Lefroy, D.Sc., of the Imperial College of Science, London, to whom the thanks of the Station are due for releasing him from his post as assistant in his Department. Mr. Staniland has subsequently been given the appointment vacated by Mr. Ballard.

At the end of April, 1924, Mr. G. S. Peren vacated his appointment as Pomologist to the Station to take up that of Sir John Buchanan Professor of Agriculture at Victoria University, Wellington, New Zealand. In view of the increase of work attached to this post at Long Ashton, it was decided to fill the vacancy by making two distinct appointments and dividing the duties, which had hitherto been of a dual character. Mr. E. Ball, B.A., has been given the post of Research Pomologist and will be concerned exclusively with the research and experimental side of the subject. Mr. J. G. Maynard, B.A., has been placed in charge of the cultural side of the field work at the Station and will serve as Practical Pomologist. Both received their earlier training at Cambridge University, Mr. Ball subsequently proceeding to research work at the East Malling Fruit Research Station and Mr. Maynard, after a period of work on fruit storage research under the Food Investigation Board of the Department of Scientific and Industrial Research, taking up practical fruit culture in Norfolk. Since in neither case could the appointment take effect until the latter part of the summer there was an important period of the season when this section of the work of the Station had to be maintained by other members of the Staff in addition to their normal duties. As a result, progress in certain investigations has been necessarily delayed somewhat.

The loss to the Station by the departure of Messrs. Ballard and Peren within a few months of each other has been particularly unfortunate in respect of the investigation on the "Red Plant" disease of strawberries for which they were jointly responsible. Arrangements have been made for continuing the work, but the progress which it had been hoped to make in 1924 has been retarded.

Mr. J. F. Ward, B.A., completed his investigation of the root systems of red and black currants at the end of May and has now left the Station to take up work in connection with the East Anglian section of the Fruit Soils' Survey.

The Advisory staff has been strengthened by the addition of Mr. R. M. Nattrass, B.Sc., who has been appointed to the newly created post of Advisory Mycologist. Mr. Nattrass commenced his duties in February, 1924.

In addition to these staff changes a very important alteration has been made concerning the administrative side of the work of the Station. Since the war the activity of Bristol University in the direction of agriculture and horticulture has rapidly increased and a definite Department of Agriculture and Horticulture, including the various branches of research and advisory work, has been established. The taking over of the Campden Fruit and Vegetable Preservation Research Station and the appointment of Dr. J. A. Hanley as Agricultural Information Officer a year ago have opened

up new fields of work. These, together with the quick growth of the research and advisory sides at Long Ashton and the development of close association with various outside bodies, have made the provision of assistance in the direction of the affairs of the Department necessary. The general charge of work under the Advisory Scheme has therefore been placed in the hands of Dr. Hanley, as Chief Advisory Officer. Mr. Appleyard, the senior member of the research staff at Campden, now serves there as Resident Director also, and Mr. T. Wallace, hitherto Advisory Chemist at Long Ashton, has been transferred from the Advisory to the Research Staff of the latter Station to act as Deputy Director. Professor Barker, the Head of the Department, will in future have their assistance in the administration of the work in the various directions indicated.

Land and Plantations.—Under this head there is little which calls for special mention. It was reported a year ago that some 20 acres of land, under grass until that time, had been drained and ploughed in preparation for new plots of fruit. The preliminary cleaning and cropping with agricultural crops is proceeding and it is expected that a portion will be fit for planting during the course of the next twelve months. The remainder it is intended to plant in the autumn of 1926.

On part of the land previously prepared, plots of strawberries for manurial experiments have been established as planned. A further small area of the same fruit has also been planted up for the continuation of other lines of investigation already in hand. In this connection it should be stated that the programme of strawberry investigations in the field unfortunately has had to be considerably modified. There were two reasons for this. In most of the plots where cultural and other related trials were in progress a seriously large percentage of the plants during the course of the summer showed signs of being affected with eelworm and other forms of pathological trouble, the nature of which is at present obscure. There is some reason to believe that the continuous wet and cold weather was responsible for the abnormal rate of spread of disease. It being evident that crop records from these would be entirely misleading, the work on them has been abandoned and the plots mostly grubbed. The second reason leading to the abandonment of some of the plots was the weakening of the plants during the summer by excessive weed growth. During the period of cropping in June and July cleaning could not be carried on owing to interference with the crop records and as a result under the wet conditions the plots became badly overgrown with weeds. It has been decided in view of the experience now gained that it is necessary first to concentrate research on the pathological aspect of strawberry culture, since reliable results from cultural experiments will be difficult to secure until adequate measures of control of

diseases and pests are discovered. Most members of the research staff are now occupied with various problems in the latter connection in the hope of solving quickly the question of control of strawberry diseases, so that the original lines of work may be resumed with as little delay as possible.

A supply of water has now been carried to the part of the farm occupied by the plantations established since the war and this will serve both for the new buildings and stabling and for spraying purposes.

Buildings.—During the year the outstanding schemes for additions to the buildings of the Station referred to in the last Report have been practically completed.

The much needed insectory and shelter for outdoor pot experiments were finished in time to be put in use for the past season and have been found of great service.

The erection of the extension of the orchard house has been deferred, since the recently added accommodation under glass has proved sufficient for immediate needs.

This has permitted of sufficient funds being available to carry out the library extension mentioned a year ago and to add another small office.

The new wing of the cider house has been in regular use. By the relief which it has afforded to the congestion in the main building it has been possible to carry on the cider work under much more satisfactory conditions. The provision of equipment for washing the fruit and for pasteurisation of the expressed juice is being found of great service.

General.—The Fruit Soils' Survey, now entering its third season, has progressed considerably during the year. The information so far gained has thrown much valuable light on the question of success or failure of the fruit plantations in the areas surveyed.

Educational exhibits have been sent during the year to the Imperial Fruit Show, the Bath and West and Southern Counties Society's Show, and the Wilts County Show. An exhibit was also sent to Worcester for the Three Counties Show, which was abandoned at the last moment owing to the flooding of the Show ground. The Station was represented in the Government Pavilion at the British Empire Exhibition at Wembley, having contributed a section to the comprehensive exhibit organised by the Ministry of Agriculture and Fisheries to illustrate the work of the agricultural and horticultural research stations of Great Britain.

A well attended Field Day was held at the Station on July 15th, 1924. The Institute was also visited during the season by nineteen organised parties and a large number of individual visitors.

Close touch is being maintained with the Botley Experimental Fruit Station. The work there has been closely associated with that at Long Ashton and duplicate trials on such subjects as the manuring of strawberries and strain selection are in progress at both centres.

During the year the first steps towards the provision of local instruction in cider making in the Western Counties generally have been taken. In pre-war days occasional instruction was given in one or two of the counties by part-time instructors employed by the County Councils; since the war very little has been done. The recent rapid growth in popularity of cider as a beverage has resulted in increased attention and interest on the part of farmers in both farm orcharding and cider making, with a corresponding desire for information as to modern methods of making. The Institute in conjunction with the Ministry of Agriculture and the County Councils of the West of England has considered the possibility of organising a joint scheme of local instruction to cover the whole area and a definite proposal has now been laid before the local authorities. As a preliminary step the Institute placed the services of Mr. Grove at the disposal of contributing counties for the major part of the 1924 season for local lectures and demonstrations in the subject. While this course necessarily involved some curtailment of the programme of experimental work in the cider-house and laboratory at Long Ashton, it has more than justified itself in demonstrating the extent of the call for local instruction and the lines on which such instruction should in future be based.

For some time the Ministry of Agriculture and the Meteorological Office have had under consideration the question of obtaining data on the nature of the correlation between weather conditions and the behaviour of crops. A scheme has now been agreed upon, to be carried out at certain research stations and other institutions in various parts of the country, by means of which a large volume of facts designed to throw valuable light on the subject should be secured. At each centre certain test crops will be grown for a period of years and a wide series of meteorological observations taken to cover the whole of that time. The Long Ashton Station is participating in this scheme, which is now in operation, the test crops in this case being certain kinds of fruits and vegetables.

In conclusion it is a pleasure to acknowledge the valuable and ever-increasing help received from members of the Committee, fruit growers and others interested in the work of the Station. Their readiness to assist by supplying information on practical points bearing on various lines of work and providing facilities for the conduct of local experiments is a gratifying testimony of their goodwill and affords material encouragement to the research worker and adviser. It is desired also to make a personal acknowledgement of the loyal co-operation of members of the Staff of all grades.

POT EXPERIMENTS ON THE MANURING OF FRUIT TREES.—IV.

BY T. WALLACE.

In the Report on these experiments for Season 1923 a statement was made to the effect that it was then becoming possible from the data available to form some general conclusions on certain of the points under investigation. Data were presented in that Report from the older experiments on apples, strawberries, black-currents and gooseberries in which the effects on the shoot growth, foliage characters, root systems, cropping, etc., of the plants resulting from deficiencies of nitrogen, potassium, phosphoric acid, calcium and magnesium respectively were being investigated, and it was shown that the effects produced by any one treatment on the different plants were very similar.

It was pointed out in that Report that it was still desirable, however, to obtain further data on certain points from those experiments, *e.g.*, further crop weights—and that certain of the results obtained called for further investigation, *e.g.*, apparent magnesium starvation symptoms induced by feeding apple trees with nutrient solutions of high potash content.

Accordingly, these older experiments were continued during 1924, and experiments were also commenced to investigate various other points brought out in the 1923 results.

In addition to these, it was decided to extend the scope of the investigations to study the following points:—

1. The effect of sulphur deficiency on the various plants.
This treatment was not included in the original deficiency experiments.
2. The effects produced on the plants by complete nutrient solutions of widely different reactions, *i.e.*, acid solutions, neutral solutions and alkaline solutions; p_H values 3.0, 6.6, 9.0*

These experiments were commenced as there does not appear to be any data available on the subject of the effect of soil reaction on fruit trees. Considerable data on this subject for agricultural

* Solutions of p_H value 3.0 are strongly acid, of p_H value 6.6 slightly acid, of p_H value 9.0 strongly alkaline.

plants exist and modern fruit practice relating to this point is based wholly on agricultural practice.

From a considerable amount of field data which the writer has collected on this point, it is quite evident that the subject calls for very careful study. The case of soil alkalinity appears to be specially important.

3. The effects produced on the plants by acid and neutral nutrient solutions deficient in phosphoric acid, p_H values 3.0, 6.6.

This point required investigation as Solution E—phosphoric acid omitted—used in the original deficiency experiments when diluted ready for application has p_H value 4.7, whereas the other solutions used have p_H values 6.4 to 6.6. The results obtained in those experiments with Solution E might therefore have been due in part to the strongly acid reaction of the solution.

The more important of the observations recorded during the season are given in the following notes on the experiments.

Weather during 1924 Season.

With the exception of a few days of sunshine towards the end of April, and in early July, the weather throughout the season was extremely wet and lacking in sunshine.

The plants not under shelter, *i.e.*, apples, gooseberries and black-currents, suffered severely at times from the heavy rain storms, and in one experiment on apples the damage from water was so severe that the trees dropped their leaves and it was impossible to pursue the investigation during the remainder of the season.

There were hard frosts on the nights of November 3rd, 4th, and after these, the amounts of foliage on the plants in many of the experiments were so small that observations on the plants were discontinued for the season.

I.—DEFICIENCY EXPERIMENTS.

(a) Experiments on Apple Trees—Variety, Cox's Orange Pippin. Commenced 1921.

The shoots of the trees in this experiment were all cut back to within 1 inch of the main stems during winter 1923-24 and thus during 1924 it was possible to make observations on the ability of the plants to make new shoot growth and on the foliage characters, etc., of the trees after having undergone the respective treatments for three seasons previous to 1924.

The data obtained relating to shoot growth are shown in Table I.

TABLE I.
SHOOT GROWTH OF APPLE TREES, SEASON 1924.

Series and Treatment.	No. of Trees in Series.	Total length of shoots per Series—m.ms.	Average length of shoot growth per tree—m.ms.
A.—Complete nutrient solution ..	4	3945	986.3
C.—Nitrogen omitted	4	100	25.0
D.—Potassium omitted	3	2110	703.3
E.—Phosphorus omitted.. ..	3	230	76.7
F.—Calcium omitted	4	5275	1318.8
G.—Magnesium omitted	4	3225	806.3
H.—Water only	4	120	30.0

The data relate only to the trees which are on Broadleaved Paradise Stock. It will be noted that from the point of view of shoot growth the series may be divided into two groups—one group comprising Series A, D, F, G, in which the shoot growth is relatively good, and the other Series C, E, H, in which shoot growth is poor.

Two further points of note are that the largest amount of shoot growth has not been made in Series A, but in Series F, and that the smallest amount has not been made in Series H, but in Series C.

As the shoots have again been pruned back to the main stems it will be possible to obtain data similar to the above next season.

(b) *Experiment on Gooseberry Bushes. Commenced 1922.*

In this experiment it was hoped to obtain further cropping data during the season and to make further observations on foliage characters and defoliation.

The data obtained relating to cropping, however, were rendered unreliable owing to the depredations of birds during the period of flowering, at which time it was necessary to keep the plants in the orchard house owing to frost and it was found impossible to keep out the birds during periods of sunshine when it was essential to ventilate the house very thoroughly.

Accordingly, the data obtained are only being used to supplement data on the size of fruits. Certain observations were also made on the character of the fruits. The only point of note which this latter examination brought out was the poor quality of the fruits from the bushes receiving the "phosphoric acid omitted," treatment in which series the fruits lacked flavour and sweetness. Similar characteristics of fruits produced by this treatment were also noted for blackcurrants and strawberries. The gooseberry fruits in this series also exhibited the dull bronzed colour and purple spotting characteristics of the foliage of the plants of the series.

The foliage of the plants in the different series were very interesting throughout the season and showed their several characteristics very markedly.

In Series A and B—complete nutrient solutions—the foliage was in excellent condition throughout the growing period.

In Series C—nitrogen omitted—and Series H—water only—the leaves and fruits were very small and as early as May 17th the foliage was practically all reddish-yellow in colour, whilst by June 27th the leaves were almost entirely of a vivid scarlet colour.

Where potassium was omitted in Series D, the leaves became suffused with purplish-red tints and showed much curling at the edges towards their under surfaces by May 24th, whilst on May 31st all the bushes exhibited brown marginal leaf scorch on the foliage.

The plants in Series E—phosphoric acid omitted—made practically no growth during the season. The amount of foliage from the beginning was relatively small and was confined to the areas near the tips of the shoots. The leaves were small, dull green in colour and soon became entirely bronzed in appearance, showing a characteristic purple spotting. A considerable proportion of the foliage was shed during a few hot days in the latter part of May and from June onwards the bushes only carried a little poor bronzed foliage.

In Series F—calcium omitted—the plants, as in former years, did not show any well defined symptoms, but from time to time the leaves looked rather pale and there were some red bands developed on them as in Series G.

In Series G—magnesium omitted—the plants made very large growth. The foliage of all plants became strongly tinted in characteristic fashion but the leaves were not shed prematurely.

Some idea of the relative growths made by the bushes during the period of experiment will be obtained from consideration of the data presented in Table II. The data refer only to bushes receiving leaching treatment.

TABLE II.
HEIGHT AND SPREAD OF GOOSEBERRY BUSHES, DECEMBER, 1924.

Series.	No. of bushes.	Height of bushes. Totals m.ms.	Height of bushes. Average per bush m.ms.	Spread of bushes. Totals m.ms.	Spread of bushes. Average per bush m.ms.
A.	7	2640	377.1	3430	490.0
C.	6	1550	258.3	1130	188.3
D.	7	2450	350	2530	361.4
E.	7	2080	297.1	2010	287.1
F.	7	2550	364.3	2610	374.3
G.	7	3090	441.4	3150	450.0
H.	7	1920	274.3	1390	198.6

With regard to the relative orders of defoliation of the plants during the season, the following observations, made on September 19th, will indicate how this proceeded.

September 19th—Order of Retention of Foliage.

Series F, A and G, B.—Very little defoliation.

Series D.—40 to 50% defoliation.

Series C and H.—Only few red leaves retained.

Series E.—Practically defoliated.

Subsequently, defoliation in Series F, A, G, B proceeded practically simultaneously.

(c) Experiment on Blackcurrant Bushes. Commenced 1922.

Further data were obtained during the season on the growth characters and cropping of the plants. The fruit crop was very small in all series as the blossom set very badly, which was most probably due to the dry atmospheric conditions obtaining in the orchard house during the blossoming period. Blossoming and fruiting were much less in Series C, E and H than in any other series as, in these series, the development of lateral buds has been greatly restricted by the treatments given.

The relative amounts of growth made by the plants in the various series were similar to those made by the gooseberry bushes under the similar treatments, those in Series C, E, and H failing to make any appreciable amounts of growth.

Of the various foliage characteristics noted during the season, perhaps the only points worthy of special mention in this report were the extreme sparsity and poor condition of the foliage in Series E—phosphoric acid omitted—and the leaf size of the plants in Series D—potassium omitted. These latter plants dropped practically all the larger leaves along their shoots during the middle of the season and retained only foliage comprised of very small leaves, which condition gave the plants the appearance of being, to a large extent, defoliated.

The amounts of shoot growth made during the season are shown in Table III.

The data refer only to bushes receiving leaching treatment.

It is of interest to note that in Series C, E, H, not only is the length of shoots restricted, but the actual number of shoots is much smaller than in the other series.

TABLE III.
SHOOT GROWTH OF BLACK CURRANT BUSHES, SEASON 1924.

Series.	No. of bushes.	Total shoot growths m.ms.	Shoot growth Average per bush m.ms.	Total number of shoots. m.ms.	Average length per shoot. m.ms.
A.	8	24885	3110.6	327	76.1
C.	8	1110	140.0	70	15.9
D.	7	15680	2240.0	346	45.3
E.	8	4715	589.4	95	49.6
F.	8	25065	3313.1	293	85.6
G	8	24035	3004.4	313	76.8
H	8	980	122.5	79	12.4

The order in which defoliation occurred is illustrated by the following notes made on September 28th.

Order of Retention of Foliage—September 28th.

Series A,B,F,G.—The individual plants of these series retained from 60 to 80% of their original foliage.

Series D.—The amount of foliage retained was less than in Series A, etc. The actual amount of defoliation was difficult to estimate owing to the replacement of the original larger leaves with later developed small leaves.

Series C,H. All practically defoliated. The bushes only retained a few semi-dried out leaves.

Series E.—All defoliated.

Defoliation in Series E commenced as early as May 31st, and on June 27th it was estimated that the plants were 80% defoliated.

(d) *Experiment on Raspberry Plants. Commenced 1923.*

As it was decided to use the plants in this experiment to obtain further growth data during 1924, the canes made by the plants during 1923 were cut away during the winter so as to deplete the food reserves within the plants and to prevent fruiting so that the efforts of the plant would be concentrated on cane growth.

Accordingly, the data accumulated during 1924 relate wholly to growth and foliage characters.

The rate of shoot development was followed throughout the season and the actual numbers of canes thrown, together with their lengths and weights, were taken after defoliation. These data are presented in Table IV.

The main points brought out by the data are as follows :—

- (a) The length of the canes was greatly restricted by treatments C, H and to a less extent by treatments D, E.
- (b) The numbers of canes per plant in Series C, E, H were smaller than in the other series. The largest numbers of canes per plant were developed in Series A.
- (c) The weights of the canes in Series C, H were very small in comparison with those in the other series. The weights were also relatively small in Series D, E.

Comparison of the data with those obtained in 1923*—the first season of the experiment—show very clearly how much the growth has fallen off in Series E in comparison with the other series during 1924. This was predicted in the Report for 1923.

The plants in Series F made better growth during the season than in 1923.

With regard to the types of foliage carried during the season, these were similar to those described for the previous season with the exception that at no time during the past season did the foliage in Series E look a healthy green. The leaves in this series remained small and were dull green with much bronzing from a very early date.

TABLE IV.
GROWTH MEASUREMENTS OF RASPBERRY CANES. SEASON 1924.

Series.	No. of plants.	Total length of canes. m.ms.	Average lengths of canes per plant m.ms.	Total No. of shoots.	Average lengths per shoot m.ms.	Total weight of canes gms.	Average weights of canes per plant gms.
A.	10	27630	2763.0	58	476.4	346.3	34.63
C.	10	2115	211.5	21	100.7	11.5	1.15
D.	10	14580	1458.0	41	355.6	139.3	13.93
E.	10	11015	1101.5	28	386.3	111.2	11.12
F.	7	17510	2501.4	32	547.2	209.2	29.89
G.	10	23610	2361.0	39	605.4	296.9	29.69
H.	10	2310	231.0	24	96.3	10.5	1.05

Defoliation.

The observations made on defoliation were spoilt to a certain extent in the latter stages by a severe attack of red spider on the plants, against which it became necessary to spray and this, unfortunately, caused considerable defoliation.

* Annual Report 1923, page 52.

The notes made, however, were sufficient to show the general trend of defoliation and these verified the results obtained in 1923. The observations made on September 14th show the general order.

Order of Retention of Foliage—September 14th.

Series A, D—50 to 60% of foliage retained.

Series F—40 to 50% of foliage retained.

Series G, E—20% of foliage retained.

Series C, H—Only retained a little foliage at the tips of the shoots.

Defoliation may be said to have been hastened to a marked extent in Series G, E, C, H. It is of interest to note the premature defoliation in Series G, as this was noted last season. It has also been observed each year on apple trees.

(e) Experiment on Strawberry Plants. Commenced 1921.

In previous reports on the plants in this experiment, data have been presented for growth and foliage characteristics during various periods of the season, for time of blossoming and fruiting and for crop weights.

Season 1924, being the fourth season over which this experiment has been continued, the plants have only made very poor growth and for the greater part of the season they have had the appearance of being exhausted. Even in Series A—complete nutrient series—the plants have remained small and the quality of the foliage has been poor. However, the relative amounts of growth made by the plants in the various series were similar to those of previous seasons whilst the foliage characters exhibited—tints, leaf size, etc.—were as described for previous years.

One interesting point with regard to the foliage of the plants in Series D—potassium omitted—was noted during the latter part of the season. After these plants had fruited most of the older foliage on the plants died down and fresh young foliage was developed. This foliage consisted of numerous extremely small leaves, which between the end of June and the middle of August made practically no growth, the plants remaining very dwarfed. Between the latter date and October 31st, these plants made more growth but never reached normal size.

Towards the end of the season the plants in all series looked very much worn out. It is doubtful whether they will be able to start into growth in 1925.

As blossom formation during the season was very irregular and the crop weights obtained very small, it was thought that no useful purpose would be served in including the data relating to these in this report and hence they have not been included.

(f) *Experiment on Sulphur Deficiency. Commenced 1924.*

Experiments on sulphur deficiency were commenced in the spring of 1924 with apple trees—variety, Cox Orange Pippin; gooseberry bushes—variety, Keepsake; blackcurrant bushes—variety, Seabrook's Black; and strawberry plants—variety, Royal Sovereign.

The procedure followed was as in previous deficiency experiments with these plants.

The solution used was made from Solution A by substituting chlorides for sulphates in every case where a sulphate was used in that solution.

Observations during the season were confined to shoot growth, foliage characters and defoliation.

With regard to shoot growth, one season is insufficient from which to draw conclusions and hence the data relating to this are not presented here.

The indications, however, are that shoot growth will be greatly restricted in apples and gooseberries. Growth in the strawberries appeared also to have been checked but the blackcurrant bushes did not show much falling off in growth over the season.

All the plants used exhibited a similar condition with regard to colour of foliage, viz :—the green colour of the leaves became very pale during July and August and, later, brilliant orange and red tints were developed. In addition, the leaves of gooseberries and strawberries developed narrow marginal red bands.

In general, it may be said that the condition of the foliage resembled that of plants suffering from partial nitrogen deficiency.

Judging from the behaviour of the gooseberry and blackcurrant bushes, it looks as though in future seasons plants under this treatment will be defoliated in advance of those receiving complete nutrient solutions.

II. EXPERIMENT TO DETERMINE THE EFFECT ON THE PRODUCTION OF LEAF SCORCH OF APPLE TREES OF ALTERING THE RATIO $\frac{\text{NITROGEN}}{\text{POTASSIUM}}$ AND OF ADDING A SOLUBLE SILICATE TO THE COMPLETE NUTRIENT SOLUTION PREVIOUSLY USED—VARIETY, COX ORANGE PIPPIN.

No definite results were obtained on leaf scorch in this experiment during the season owing to the fact that in all the series the trees lost a large percentage of their foliage from the action of the excessively heavy rains and the foliage which was retained did not show any considerable amount of leaf scorch under any treatment.

The observations made in 1923 on the point that in the series where the trees were fed with a nutrient solution containing relatively high amounts of potash salts the leaves exhibited centre

blotches of dead tissue similar to those produced by magnesium deficiency were verified.

Further results obtained on this point on apples, blackcurrants and gooseberries are reported overleaf. (*Experiment III*).

The effects produced by the rain on the leaves of these trees led to another line of investigation being pursued during the year the results of which will be reported elsewhere.

This experiment has been discontinued as the results which have been obtained to date in this and other experiments of a similar character have furnished the data required of them.

III.—EXPERIMENT ON THE RATIO $\frac{\text{POTASSIUM}}{\text{MAGNESIUM}}$ IN NUTRIENT SOLUTIONS.

As previously stated, these experiments were commenced as the result of observations made in 1923 on apple trees fed with a complete nutrient solution having a relatively high $\frac{\text{potassium}}{\text{magnesium}}$ ratio. The trees so fed developed symptoms of leaf blotching characteristic of leaves of apple trees fed with nutrient solutions deficient in magnesium.

In order to discover whether the blotching was due to this ratio, it was decided to test the solution used in that experiment on gooseberry and blackcurrant bushes as these plants show magnesium deficiency symptoms in a manner dissimilar from apple trees and from each other and further to endeavour to check the development of the symptoms by feeding plants with a solution containing the same amount of potassium as in the previous solution but with the amount of magnesium increased threefold.

The following plants were used in the experiment :—5 apple trees—variety, Cox Orange Pippin; 10 gooseberry bushes—variety, Keepsake; 10 blackcurrant bushes—variety, Seabrook's Black.

The two nutrient solutions were marked S and K respectively, S having the high $\frac{\text{potassium}}{\text{magnesium}}$ ratio. All five apple trees were fed with

Solution K, as trees fed with Solution S were already available for comparison, whilst of the gooseberry and blackcurrant bushes, five of each received Solution S and five Solution K. The solutions were applied to the plants as in the other pot experiments and the sand was leached through as usual at short intervals.

The observations made on the plants were as follows —

Apple Trees.—The foliage in Series K became affected with blotch to a slight extent, but never to the degree of that on the trees fed with Solution S where blotch was very severe and led to much premature defoliation.

The shoot growth and size of the leaves in Series K were also smaller than in Series S.

Gooseberry Bushes.—There was a very marked difference between the foliage of the bushes in the two series from July 16th to the time of defoliation. By July 16th, the foliage of all plants receiving Solution S was showing marked symptoms identical with those associated with magnesium deficiency whilst that in Series K was fresh and green. Eventually two plants in Series K developed the symptoms, but these were never severe. During the latter part of the season the foliage in Series S became very poor whilst that in Series K remained normally green. Defoliation took place at an earlier date in Series S than in Series K the plants in the former series having lost approximately 40% of their summer foliage by October 22nd, whereas on that date, in the latter series, the plants had not lost 20% of their foliage.

Blackcurrant Bushes.—The plants in both series made excellent growth throughout the season, and there were no differences in the appearance of the plants until August 23rd. On this date it was noted that the older foliage of the plants receiving Solution S was dying down more quickly than that of the plants receiving Solution K. From this date defoliation proceeded more quickly in Series S than in Series K, whilst the plants in the former Series also showed much more purpling of the foliage than did those in the latter Series.

Thus with all three test plants the tendency during the season was for the foliage of the plants receiving the high $\frac{\text{potassium}}{\text{magnesium}}$ ratio to exhibit symptoms of magnesium starvation, whereas those receiving the lower $\frac{\text{potassium}}{\text{magnesium}}$ ratio did not show the symptoms to anything like the same extent.

It is possible that this ratio, $\frac{\text{potassium}}{\text{magnesium}}$, is of importance in apple and raspberry culture in cases where dung is not procurable as with these plants magnesium deficiency is attended by very serious premature defoliation. Strawberry plants also appear to suffer rather badly under certain conditions when receiving a diet low in magnesium. Gooseberry and blackcurrant bushes have not suffered to the same extent as the above plants in pot experiments carried out at this Station.

IV.—EXPERIMENTS WITH COMPLETE NUTRIENT SOLUTIONS OF WIDELY DIFFERING P_H VALUES—3.0, 6.6, 9.0.

The reasons for carrying out these experiments are given earlier in this report.

Experiments were commenced on the following plants :—

Variety.			
APPLES		Devon Quarrenden	6 trees per treatment.
GOOSEBERRIES	..	Keepsake	5 bushes „
BLACKCURRANTS	..	Seabrook's Black ..	5 „ „
RASPBERRIES	..	Bath's Perfection ..	3 plants „
STRAWBERRIES	..	Royal Sovereign ..	5 „ „

The plants are being grown under conditions of treatment similar to those in the other pot experiments but the sand is never leached.

The solutions used are designated Acid A with $p_H=3.0$, A with $p_H=6.6$, Alkaline A with $p_H=9.0$, Solution A being the complete nutrient solution in general use in the pot experiments, whilst the other two solutions are made from it by adjusting the p_H values to the desired figures by the addition of the necessary amounts of sulphuric acid or caustic soda solutions.

The results obtained to date have not been very pronounced with any of the plants, although there were indications towards the end of the season that the acid solutions were producing definite effects on the apple trees, blackcurrant bushes and strawberry plants. It would be premature, at this stage of the investigation, to deal in detail with the observations made and hence these are being withheld for the present.

V.—EXPERIMENTS WITH NUTRIENT SOLUTIONS DEFICIENT IN PHOSPHORIC ACID WITH p_H VALUES 3.0, 6.6.

These experiments are being carried out on apple trees—variety, Cox Orange Pippin; gooseberry bushes—variety, Keepsake; blackcurrant bushes—variety, Seabrook's Black; and strawberry plants—variety, Royal Sovereign.

Ten plants are under treatment in each experiment—five per treatment—except in the case of the apple trees where five only are being used, no treatment with solution with p_H value = 3.0 being given.

The solutions used are made from the stock solution E, which contains no phosphoric acid, by adjusting to the required p_H values. The series were designated E— $p_H=3.0$; EN— $p_H=6.6$.

The procedure followed is as for other pot experiments, the sand being leached with water at intervals.

From a very early date in the season all plants under experiment showed very markedly the symptoms which have been produced in all previous experiments with the original Solution E, which is a complete nutrient solution less phosphoric acid and has p_H value 4.7. These symptoms, which have been described in previous

Reports, take the form of bronzing and purple spotting of the foliage, such affected foliage being shed at a very early date during the season.

The symptoms were first noted on the various plants in the experiment on the undermentioned dates and appeared practically simultaneously in both series for the different plants.

Apple trees	July 16th.
Gooseberry bushes ..	July 16th.
Blackcurrant bushes	June 27th.
Strawberry plants ..	June 27th.

The symptoms developed very rapidly on all plants after these dates and shoot growth was greatly in arrears of other plants, receiving complete nutrient solutions whilst the plants were defoliated at early dates.

During the latter portion of the season the gooseberry and blackcurrant bushes in Series E were in rather worse condition than those in Series E N, but the differences were only slight.

From the results obtained during the season there appears to be no doubt that bronzing and purple spotting of the foliage and the various other symptoms which have been produced on plants receiving the nutrient solution E (phosphoric acid omitted with $p_H = 4.7$) are to be attributed to deficiency of phosphorus.

NOTE ON THE DEVELOPMENT OF ROOT SYSTEMS OF WILLOW CUTTINGS NUTRIENT SOLUTIONS.

BY T. WALLACE AND H. P. HUTCHINSON.

The experiments described herein were undertaken in order to see whether results could be obtained in a relatively short time on the characters of root systems developed by woody plants in nutrient media lacking in one of the essential elements of plant food.

Similar experiments on various fruit trees and willows in sand culture have been in progress at this Station during the last few seasons, but by this method results on the subject of root formation only become available very slowly.

It occurred to us that such results might be obtained relatively quickly by growing willow cuttings in water culture as it has been noted in the case of previous experiments that willow sets will root and shoot freely in water when cut from the plant at any time during the growing season. Accordingly, sets 10 inches in length were taken from a variety of the species *Salix triandra*, and in order to secure uniformity in size and condition of growth the terminal portions of equally sized and equally developed rods were used.

The solutions used in the experiment were as under and were those in general use at this Station for pot culture work.*

A.—Complete nutrient solution.	pH 6.8.
Acid A.—,, ,,	pH 3.0
C.—,, ,,	less nitrogen
D.—,, ,,	potassium
E.—,, ,,	phosphoric acid
F.—,, ,,	calcium
G.—,, ,,	magnesium
H.—Water only.	

The water used in making up the nutrient solutions was in every case distilled water.

The solutions in which the cuttings were immersed were contained in boiling tubes—100 cc. of solution per tube—and the tubes were

* Annual Report of this Station 1921, p. 43.

plunged in silver sand in plant pots. Three tubes were plunged in each pot and were passed through holes in cardboard discs covering the pots, the object of the discs being to prevent the sand from becoming heated to a high temperature by the sun's rays.

The nutrient solutions were changed very frequently to prevent the volumes of the nutrient solution in the tubes becoming appreciably reduced.

The cuttings were immersed immediately after cutting in the nutrient solutions—three per treatment in one tube—on February 28th and during the whole time of the experiment, which lasted until August 1st, the tubes were kept in a cold greenhouse.

The cuttings were breaking into growth at the time of transferring to the nutrient solutions and suffered a check from the operation. External lenticelar tissue development along the portion of the cuttings immersed in the solution was noted after three days and root protrusion and bud burst were complete after twelve days. There were no differences between the amounts of growth made under the various treatments to this date, but from this time differences both of shoot and root development became marked.

From April 1st onwards the cuttings made excellent growth, of both shoot and root, in the complete solution A, and by April 30th large root systems had been made. On this date the roots of two plants per treatment were shaved off with a sharp razor and the plants replaced in their respective solutions to make new root systems, one cutting per treatment being left untouched.

By June 11th the treated shoots in Series A had again made good root systems and the root pruning as for April 30th was repeated on the two cuttings per series previously treated. The plants were grown on again until August 1st, during which period further root systems were developed.

It was thought that by such pruning we should deplete the food reserves so thoroughly as to obtain a true picture of the root systems as influenced by the respective nutrient treatments.

The root systems of the cuttings were kept under close observation during the whole period of the experiment, photographs of those of the treated plants being taken on April 26th, June 11th and August 1st, just previous to the pruning operations.

The various characteristics of the root systems noted are given below.

Before dealing in detail with the observations made on the root systems it will be of interest to deal briefly with the nature of the shoot growth of the cuttings of the various series.

Series A.—From an early stage shoot growth was very vigorous and healthy.

Series Acid A.—Similar to A.

Series C.—Shoot growth poor and leaves yellowish green.

Series D.—Poor. Leaves had developed "Chlorosis" by April 30th.

Series E.—Poor. Leaves dull green colour.

Series F.—Poor. Leaves were strongly "Chlorotic" by April 30th.

Series G.—Shoot growth as A.

Series H.—Growth very poor.

The shoot growth as above was severely checked by the root prunings, so much so that after the second pruning operation shoot growth was almost at a standstill in all series. The cuttings, however, continued to make considerable root growth except in G and H. in which series the plants were practically killed by the second pruning.

ROOT SYSTEMS.

April 1st.—On this date the root systems in Series A, Acid A, and G were making excellent growth both of primary roots and secondary fibre.

D and E were somewhat behind the above and the fibre was proportionately less in amount to the amount of primary roots.

F, C and H were smallest, the amount of secondary fibre being larger in C than in F and H.

April 26th.—By this date there were well marked differences between the root systems of the various series.

A, Acid A, E and G.—These roots were similar in appearance, the plants having made good growth of primary roots and plenty of secondary fibre. A roots were somewhat larger than those of the other series.

D.—The primary roots in this series were fairly well developed but the growth of the secondary fibre was very poor.

C.—The primary roots were much shorter and thinner than A. and the secondary fibre was rather poorer in proportion.

F.—Both primary roots and secondary fibre were poorly developed.

H.—Primary roots were very small and secondary fibre practically undeveloped.

April 30th—First root pruning operation carried out.

OBSERVATIONS ON ROOT PRUNED PLANTS.

May 24th. A, Acid A, and G.—Primary roots and secondary fibre were again well developed.

C.—The root systems were much smaller than A, but the amounts of primary roots to secondary fibre were normal in character.

D.—Primary roots were fairly well developed but there was scarcely any secondary fibre.

E.—One root system was rather poor. The other, although somewhat smaller than in A. was normal as regards the relation of primary roots to secondary fibre. The poor root was yellowish pink in colour.

F.—The primary roots were very poor and there was practically no development of fibre.

H.—Practically no root development.

May 31st.—By this date the lack of fibre in relation to the amount of primary root development had become accentuated in Series D and F.

June 13th.—Second root pruning operation carried out.

June 27th.—A, Acid A.—Both primary roots and secondary fibre developed

C.—One plant, primary roots and secondary fibre developed. Other plant, poor development.

D.—Thin primary roots thrown. No secondary fibre.

E.—One plant, thin primary roots with secondary fibre. Other plant, poor development.

F.—Fairly long primary roots thrown. No secondary fibre.

G.—Very poor development in both plants. Practically killed by the second pruning.

H.—No roots.

July 16th.—To this date the roots had developed along the lines indicated under June 27th : Series D and F plants failing to make secondary fibre of any size in proportion to the primary roots made by them.

No roots were made by the plants in Series H.

In all other series, although the root systems were of varying sizes, the amounts of secondary fibre developed were in proportion to the growths of primary roots.

Observations made between this date and August 1st, when the experiment was concluded, were similar to those recorded on July 16th and served to make clear the point that the root systems

formed by plants in the solutions D and F, from which potassium and calcium respectively were omitted, were markedly deficient in secondary fibre.

CONCLUSION.

As the result of observations made in this experiment we are particularly desirous of drawing attention to the characters of the root systems formed by growing cuttings in nutrient solutions deficient in potassium and calcium respectively.

In both cases, the observations point to the fact that under such conditions the root systems are markedly deficient in fibre.

We may say that we obtained identical results in similar experiments which we carried out in 1923 and a similar result was obtained by one of us (T.W.), with apple trees in sand cultures in 1921 in cases where potassium was omitted from the diet of the trees.

THE PHYSIOLOGY OF THE NUTRITION OF FRUIT TREES.—I. SOME EFFECTS OF CALCIUM AND POTASSIUM STARVATION.

BY C. E. T. MANN.

Problems bearing on the nutrition of various fruit trees have formed subjects of investigation both in this country and in America for some time past. Primarily these problems were investigated in the field, but results obtained from many field experiments have been shown to have only a limited application. Under field conditions, on any experimental plot, generally only one or two special points can be studied and so many factors difficult to control are usually present that the interpretation of results is rendered very difficult. Such experiments with fruit trees are also very costly as they require large areas of land and considerable labour for their proper conduct whilst results are only obtained very slowly.

To obviate the difficulties and limitations presented by field experiments workers in the past have employed the method of pot experiments by which various problems may be studied under conditions which allow of much stricter control than is possible in the field. In such experiments plants are grown in sand or water cultures and the various factors of the problem under investigation may be studied by more or less refined laboratory methods.

Typical examples of the application of this method to problems of plant nutrition are afforded by the work of Hoagland (6,7) on the nutrition of cereal crops, of Reed and Haas (12,13) on the "mottle-leaf" of citrus trees and of Wallace (15) on the nutrition of apples, blackcurrants, gooseberries and strawberries.

With reference to the work on fruit trees, the sand culture method employed in these experiments has many obvious advantages over the field method in the study of special problems. The plants are grown in sand to which the various mineral foods may be supplied as desired in the form of culture solutions. External conditions of light, temperature and humidity may be controlled and furthermore the difficulty of pest control, which has often greatly vitiated the results of many field experiments, is minimised.

In applying this method to the solution of nutritional problems it is usual to test the conclusions arrived at in the pot experiment

by field experiments selected as likely to provide the necessary test conditions.

The following will serve as concrete examples of nutritional problems which have been studied by pot culture methods.

- (a) The effects produced on plants of deficiencies of the various essential elements of food.
- (b) The effect of varying the ratios of the elements of plant food in culture solutions on the growth and development of plants.
- (c) The influence on growth of excess of any particular essential element, e.g., nitrogen or potassium.

Much of the work previously carried out on such problems has been of a qualitative nature.

In deficiency experiments valuable information has been recorded on the appearance exhibited by various fruit trees when certain elements of the plant food are withheld (15). When phosphates were withheld trees or bushes showed very weak growth and defoliated extensively at an early date so that only a small amount of foliage, near the tips of the shoots, was retained during the greater part of the season. Again, if potassium salts were omitted the foliage on the plants in these cultures invariably suffered from leaf-scorch. Throughout the experiments it has been shown that the omission of a single element from the "complete" culture solution supplied is reflected in the growth of the plant and normal development does not proceed in the absence of one of the essential elements. Each essential element thus constitutes a limiting factor in the growth of a plant. If one of these elements be deficient, though the remainder be present in adequate amounts, growth and development will be limited by the deficiency.

In experiments in which the proportions between certain elements in the culture solution was varied it was shown that these variations were reflected in the plant. Apple trees grown in sand cultures received a culture solution containing an insufficient amount of potassium and a small amount of leaf-scorch was observed on the foliage. By increasing the amount of nitrogen in the culture solution leaf-scorch became considerably more severe. When the proportion of nitrogen was decreased leaf-scorch did not develop. These observations indicate that in the absence of an adequate supply of potassium the trees were unable to support the area of foliage produced. The suggestion is supported by the fact that when the production of large leaves is stimulated by the addition of nitrogen leaf-scorch, which reduces the area of living foliage, becomes more pronounced. Conversely, by reducing the nitrogen supply and consequently rendering the plant less vigorous vegetatively, the potassium supply appears to be adequate for the smaller



Photo.]

PLATE II.

[W. Camps

Comparable trees from Series M.A. and M.F. The tree on the left is the same as M.A. in Plate I which received a complete culture solution. The tree on the right (M.F.) received no calcium salts. Note the stronger shoot growth and very much larger leaves of the calcium starved tree as compared with the tree which received a complete culture solution.

employed. Periodically excess water is added to each pot, the water being allowed to drain out, thus carrying away any excess of soluble compounds.

On April 4th thirty maiden trees, of the variety Cox's Orange Pippin on broadleaved Paradise stock, were planted in large waxed pots. These trees were divided into three series of ten and culture solutions were supplied throughout the season. To the first series (Series M.A.), a "complete" culture solution was supplied, the composition of which is given below.

COMPOSITION OF COMPLETE CULTURE SOLUTION. M.A.

Potassium nitrate.. ..	8.0 grms.
Sodium chloride	1.0 ..
Di-potassium mono-hydrogen phosphate ..	1.0 ..
Calcium sulphate	1.0 ..
Magnesium sulphate 7H ₂ O	1.0 ..
Ferric chloride	0.4 ..
Distilled water	1 litre.

This stock solution was diluted with 9 litres of water for application.

To the second series (Series M.D.), a culture solution containing no potassium was supplied. This solution was a modified form of the "complete" solution in which the potassium salts were replaced by the necessary quantities of corresponding sodium salts.

The third series (Series M.F.) received a culture solution containing no calcium. This solution was similarly prepared by substituting the requisite amount of sodium sulphate for the calcium sulphate used in the complete solution.

Five trees in each of the series M.D. and M.F. received culture solutions prepared and diluted with distilled water. The remaining trees received solutions diluted with rain water.

After planting, two trees from each series were placed in an orchard house and the remainder were set up in the open.

Observations were made on all the trees at various intervals throughout the growing season. A summary of the observations made on the trees of each series growing in the open is given below. The main points of difference between these trees and those placed in an orchard house are described at the end of the summary.

General Observations.

The trees in all series, except one in Series M.A., made a satisfactory start and no marked differences were observed during the first three weeks.

June 13th.

Series M.A. (Complete culture solution).

The trees in this series appeared quite normal. Shoot growth was good and the foliage healthy.

Series M.D. (Potassium omitted.)

The trees in this series were behind those in Series M.A. in general development. Shoot growth was less vigorous and rather spindly. The leaves appeared rather darker green and the leaf tips in many cases showed a tendency to curl towards the under surface.

Series M.F. (Calcium omitted).

The general development of the trees in this series was slightly in advance of that in the Series M.A. Shoot growth was stronger and the leaves appeared slightly larger.

June 24th.

Series M.A. ("Complete" solution).

Normal growth had occurred and the foliage was healthy.

Series M.D. (Potassium omitted).

On the newly developed shoots the lower leaves except those forming the basal rosette were suffering from leaf-scorch. Typical stages of this trouble were observed from the leaf with the scorched tip to the stage in which the margin of the leaf was completely affected. In severe cases the scorched leaves had fallen.

Leaf-scorch was equally severe on all the trees and no significant differences were observed between the trees receiving the culture solution prepared with rain water and those receiving the same solution prepared with distilled water.

Series M.F. (Calcium omitted).

The general growth and vigour of the trees in this series was clearly in advance of that of the trees in Series M.A. The foliage produced was healthy and the leaves were larger than those in the "complete" series.

There were no observable differences between those trees receiving rain water solutions and those receiving distilled water solutions.

Comparable trees from each series were photographed on this date and the general appearance of the trees is shown in Plates I and II.

June 28th.

A form of "spotting" was observed on the foliage of some trees in each series. The leaves affected showed small areas of dead tissue which appeared sporadically in the leaf-blade. The death of the leaf tissue appeared to follow a purplish discolouration of the cells in the affected area and this purplish colour was

often observed around the dead spots which increased in size progressively. The same "spotting" was observed on other trees of the same variety in pot experiments and in the plantations.

This trouble was not confined to the foliage of the trees of any particular series but was generally slight in all.

Apart from this observation the general observations on the three series were essentially the same as those recorded above.

July 7th.

Series M.A. ("Complete" culture solution).

The general development of the trees was good but the older leaves in certain cases no longer exhibited a normal healthy appearance. In these leaves portions of the leaf-blade, between the sub-main veins and roughly mid-way between the main vein and the margin of the leaf, appeared to be affected. In the early stages small dull green areas were observed in these positions, the dull appearance seemed to be due to complete drying out of the cells in these regions. Later stages showed, in the centres of the affected portions, patches of dead tissue. These dead areas increased in size progressively both towards the main vein and towards the margin. The leaves affected exhibited a "blotched" appearance, the "blotches" being separated by narrow regions of healthy tissue abutting on the veins. In severe cases the "blotches" had so increased in size that the centre of the leaf, except for these narrow regions along the veins, was quite dead. This symptom, which for convenience and from appearance has been termed "blotching," was quite distinct from the spotting trouble previously observed. Frequently both were observed on a single leaf.

Series M.D. (Potassium omitted).

Leaf-scorch was severe on the foliage of all the trees. Extensive defoliation had occurred. The latter formed leaves were considerably smaller than those in Series M.A. A small amount of spotting was noted but careful examination failed to reveal any sign of the "blotching" symptom described above.

Series M.F. (Calcium omitted).

Shoot and foliage development was well in advance of that in Series M.A.

"Blotching" was observed on the older leaves in this series and appeared to be slightly more severe than in Series M.A.

August 7th.

Series M.A. ("Complete" culture solution).

The trees were still growing vigorously and producing strong growths and healthy foliage.

The lower leaves showed severe "blotching" and some defoliation of affected leaves had occurred.

Series M.D. (Potassium omitted).

The general growth of the trees was poor in comparison with the trees in Series M.A.

Extensive defoliation of badly scorched foliage had occurred.

No sign of "blotching" was observed.

Series M.F. (Calcium omitted).

The same general differences between the trees in this series and those in M.A. were observed. "Blotching" of older leaves was more severe than in M.A. and more extensive loss of affected foliage had occurred.

Observations made at subsequent periods differed little from those recorded above. "Spotting" of the foliage increased in severity with the advance of the season. Defoliation of leaves suffering from blotching continued in the two Series M.A. and M.F. In the Series M.D. it was observed that the later formed leaves were considerably smaller than the leaves in Series M.A. These leaves were less severely scorched and defoliation was checked. No sign of blotching was observed at any time during the season in this series. On October 24th the trees in all three series retained a small amount of foliage. Defoliation was complete on the following dates. Series M.D.—October 28th, Series M.A.—November 4th, Series M.F.—November 19th.

The observations made on the two trees from each series which were placed in the orchard house immediately after planting differed little from those already recorded. The warmer atmosphere had the effect of "forcing" the trees into vigorous growth at an early date so that in these trees, growth and general development was considerably in advance of that of similar trees in the open during the first half of the season. This more rapid development probably accounted for the earlier appearance of leaf-scorch, on the trees of the "no potassium" series, observed on June 10th, two weeks before it was noted on the trees in the open. "Blotching" of the older leaves in Series M.A. and M.F. was also observed at an earlier date. "Spotting" was not observed on the foliage of the trees of either series in the orchard house at any time during the season. The differences in the size of the leaves produced in the three series were accentuated.

Leaf Measurements.

On June 23rd, the ten youngest leaves on all the shoots of the current year's growth were measured on the two trees of each series growing in the orchard house. Leaf areas were calculated

and these are presented in Table Ia. Later in the season (July 30th) similar measurements were made on the leaves of the trees of Series M.A. and M.F. growing in the open. Table Ib.

TABLE I.

THE EFFECT OF THE COMPOSITION OF THE CULTURE SOLUTION ON THE AREA OF THE LEAVES PRODUCED BY APPLE TREES IN SAND CULTURES.

(a) TREES IN THE ORCHARD HOUSE. JUNE 23RD.

Series	Culture solution supplied.	Leaf Areas in Sq. Cms. In order of development.										Totals.	
		Apex.											Base.
		1st leaf	2nd leaf	3rd leaf	4th leaf	5th leaf	6th leaf	7th leaf	8th leaf	9th leaf	10th leaf		
M.A.	"Complete" Omitting potassium Omitting calcium.	2.05	4.32	8.67	13.96	18.46	19.30	18.40	17.42	15.39	12.32	130.29	
M.D.		1.43	5.16	8.32	10.44	12.80	12.98	12.32	14.38	11.36	8.28	97.47	
M.F.		3.54	7.97	13.43	22.68	32.64	36.42	37.62	41.60	40.64	27.86	264.40	

(b) TREES IN THE OPEN. JULY 30TH.

M.A.	"Complete"	4.93	9.31	16.0	18.76	21.22	21.24	20.44	20.8	20.4	19.18	172.28
M.F.	Omitting calcium	4.3	10.96	16.18	22.52	26.17	27.50	25.10	23.96	23.14	24.26	204.09

It is generally believed that the supply of water is a factor in the production of large leaves. Heinicke (5) has shown that apple twigs abundantly supplied with water produce larger leaves than similar twigs receiving a smaller water supply. From the data recorded on the area of the leaves produced in the various cultures it appears possible that the differences in the size of the leaves may be due in part to alterations in the water supply maintained by the trees. Assuming that the trees in Series M.A., receiving a "complete" culture solution, maintain a normal water supply, then potassium starvation may result in a reduction of the normal water balance whilst calcium starvation may result in the maintenance of a higher water balance. The position of the water balance within a plant is determined by the power of the roots to maintain the supply and the power of the leaves to resist excessive loss. If the water supplying power of the roots of the trees in the three series is equal, then the maintenance of the water balance rests with the leaves. The rate of water loss will depend on the nature of the leaves. Should the leaves produced vary in their power to resist water loss the total area of foliage produced would bear a definite relation to this resisting power as the amount of water lost will determine

the amount available for foliage development. Thus it would appear, in the three series of experimental trees described, potassium starvation may reduce the resistance of the leaves to water loss, whilst calcium starvation may increase this resisting power. There is, however, the second possibility that the water supplying power of the roots may be affected by the omissions. It has previously been shown, in the case of apple, that the omission of potassium from the culture solution supplied restricts root development. This restriction is particularly noticeable in the roots of the second and third orders, so that the finer fibrous roots, which constitute the bulk of the absorbing surface, are relatively poorly developed. As a result of this poor root formation the water absorbing power of the root system will be considerably reduced. Thus when potassium is omitted from the culture solution, the water supply to the shoot will be diminished and this fact in itself may account for the smaller size of the leaves produced on the trees in Series M.D. With the advance of the season, when conditions become favourable for more rapid loss of water from the leaves, the supply of water maintained in the potassium starved trees, which may have been just sufficient to support the foliage produced under less extreme conditions, becomes inadequate. The failure of the water supply to the leaves may be followed by the complete drying out of the portions of the leaves, namely the margins and tips, most exposed to drying influences. Chemical changes, which go on in these dried-out portions of the leaf tissue on exposure to a damp atmosphere result in the typical appearance of leaf-scorch (14).

The omission of calcium from the culture solution appeared to have little influence on root development as compared with that of trees receiving a "complete" culture solution. The differences noted, though slightly in favour of the calcium starved trees, seemed much too small to account for large differences in absorbing power. The main factor in preserving the water balance in the trees of the two series would appear to be the resistance of the foliage to water loss.

The observations made on those trees from each series which developed in an orchard house afford additional evidence in support of the views advanced. Throughout the growth period much drier and warmer conditions prevailed in the orchard house than in the open air. Consequently the conditions for rapid loss of water from the leaves were much more severe inside than in the open. The early appearance of leaf-scorch on the trees in Series M.D. (potassium omitted) and its subsequent rapid development shows that the drying conditions favoured its advance. The large difference in the size of the leaves in the two series M.A. and M.F. serves to emphasise the effect of the omission of calcium on the power of the plant to maintain a high water balance.

The "blotching" symptom observed on the leaves of trees in the "complete" and "no calcium" series appeared to be identical with a symptom previously observed (15) on the leaves of apple trees growing in cultures from which magnesium was omitted.

The ratio of potassium to magnesium in the culture solutions employed was high, a condition which has been shown to favour the appearance of this symptom.

EXPERIMENTS ON THE WATER RELATIONS OF GOOSEBERRY BUSHES AND APPLE TREES RECEIVING VARIOUS CULTURE SOLUTIONS.

I. Comparison of the water content of the leaves of gooseberries receiving three culture solutions.

Three samples of shoots, of the current year's growth, were collected from three series of gooseberry bushes in sand cultures as follows:—

One sample from bushes receiving a complete culture solution.

" " " " " " minus potassium.
 " " " " " " minus calcium.

The samples were taken in the evening and each sample was placed in a beaker containing distilled water. The three samples were removed to the laboratory and covered with a large bell jar overnight. This procedure was followed in order that the leaves of all the shoots should reach their maximum water content under the same conditions. On the following morning the leaves from all the shoots were removed as rapidly as possible and the three samples quickly weighed. The three weighed samples were dried to constant weight at 98° C. and the water content of each sample was obtained. The results obtained in four experiments are given in Table II.

TABLE II.

THE EFFECT OF THE COMPOSITION OF THE CULTURE SOLUTION SUPPLIED ON THE WATER CONTENT OF THE LEAVES OF GOOSEBERRIES IN SAND CULTURES.

Date of Experiment.	Water content of leaves as percentages of fresh weight.		
	Complete culture solution.	Potassium omitted.	Calcium omitted.
20/5/24	76.2	69.8	75.0
21/5/24	74.7	69.2	75.7
27/5/24	70.4	64.9	72.4
14/6/24	70.74	62.44	76.03

The results of the foregoing experiments show that in the case of gooseberry the omission of potassium from the culture solution is reflected in the lower water content of the leaves produced. The omission of calcium seems to favour the maintenance of a higher water content by the leaves.

II. Comparison of the rates of water loss from detached leaves of gooseberries receiving three culture solutions.

To follow more particularly the rate of water loss from gooseberry leaves produced in the three cultures the above experiment was repeated with the following modification. Instead of drying the leaves rapidly at 98 ° C. the rate of dehydration was followed at a lower temperature. As soon as the detached leaves from the three samples had been weighed they were suspended by the petioles from previously weighed cotton threads. Each sample was weighed at intervals of one hour and the hourly loss of weight was recorded over a total period of seven hours. Preliminary experiments showed that in order to obtain comparable results it was necessary to allow the leaves to dry out in still air at constant temperature. The samples were therefore suspended in an incubator oven at 25° C.

In the case of gooseberry, when potassium is omitted from the culture solution, the first symptom observed in the foliage is a red colouration. This reddening of the foliage is followed later in the season by the appearance of marginal leaf-scorch on the pigmented leaves. Exactly similar stages have been observed in the field where gooseberries are subject to leaf-scorch.

Experiments were performed as described above at various dates throughout the season. In the tables given below (Table III) the results of two experiments have been summarised. The first experiment was carried out on comparable leaf samples before the red pigmentation of the leaves in the "no potassium" series had appeared. The second experiment was performed later in the season when the red colour of the leaves in this series was well marked but before actual leaf-scorch had appeared.

TABLE III.

THE EFFECT OF THE COMPOSITION OF THE CULTURE SOLUTION
SUPPLIED ON THE RATE OF WATER LOSS FROM DETACHED
LEAVES OF GOOSEBERRIES GROWN IN SAND CULTURES.

Time in hours.	May 21st.—Temperature : 18 C.			June 14th.—Temperature : 25 C.		
	Percentage of Total Water lost from the leaves.			Percentage of Total Water lost from the Leaves.		
	"Complete" solution.	Omitting potassium.	Omitting calcium.	"Complete" solution.	Omitting potassium.	Omitting calcium.
	Leaves : green.			Leaves : pigmented.		
1	12.8	12.6	8.5	34.7	36.8	15.3
2	15.0	16.0	10.5	42.6	51.7	19.7
3	16.7	18.2	11.6	50.8	—	—
4	18.3	20.0	12.5	56.9	70.3	25.9
5	20.3	21.9	13.4	61.2	75.8	28.9
6	22.3	23.7	14.4	64.8	79.8	31.3
7				68.0	83.4	33.4

The results of the two experiments are not strictly comparable as dehydration occurred at different temperatures in the two cases. The results presented, however, indicate that leaves from the bushes receiving no potassium are less able to resist dehydration than leaves from either of the other series. The omission of calcium tends to increase considerably the power of the leaf to resist water loss. The loss of water from leaves produced in the absence of potassium seems to occur more readily from leaves showing red pigmentation.

It has recently been shown (10) that the absence of potassium or calcium from the plant food may have a considerable influence on the nature of the exposed surfaces of living tissues. The outer walls of the epidermal cells of a leaf are protected by the cuticle which is virtually a vegetable varnish, composed of compounds of calcium, potassium or sodium with complex fat compounds. It has been shown that when potassium is deficient the cuticle is thinner than that formed on leaves from plants receiving a complete culture solution. When calcium is omitted a thicker cuticle is produced than in any other series. It is probable, therefore, that the differences in resistance to dehydration recorded above may be accounted for in part by the difference in the degree of protection afforded by the cuticle in the three samples.

III. Comparison of the transpiring power of the leaves of apple trees receiving three culture solutions.

Transpiration, i.e., the loss of water from a leaf, has been shown to depend, apart from the external factors, on the water content of the leaf and the size of the stomatal openings (8, 9). Loss of water from the leaf which occurs even when the stomata are closed is termed cuticular transpiration and will depend on the nature of the cuticle. Since both the water content of a leaf and the nature of the cuticle are affected by either potassium or calcium starvation it appeared probable that the transpiration rate under these conditions might also be affected.

Using a standardised hygrometric paper method as employed by Livingston (11) and Bakke (1) an attempt was made to compare the transpiring power of leaves of the apple trees in the three series. Comparable shoots of the current year's growth were selected from trees of the three series M.A., M.D. and M.F. One shoot from each series bearing seven leaves was supported with the cut end in a tube of distilled water. The transpiring power of similarly placed leaves on each of the three shoots were compared at intervals of one hour. It was found at the outset that the rate of loss of water from the upper surface of an apple leaf was very slow in comparison with the rate of loss from the lower surface. To obtain comparable results it was necessary to carry out the operations as

rapidly as possible on all three shoots, hence determinations were only made on the under surface of the leaves. Each determination was performed in triplicate for each leaf.

The results obtained in these experiments are best presented graphically. In the accompanying figures comparative transpiration rates are plotted against time and observations of the light conditions obtaining during the period of the experiment are also included. (Figs. I and II. See next page.)

The results of the foregoing experiments, of which those presented in Figs. 1 and 2 are typical, are at present too few to admit of a general interpretation. The results obtained indicate that the rate of transpiration from the potassium starved leaves is lower on the whole than that from leaves of the other two series. This fact may be correlated with the lower water content of these leaves, since it has been shown, that provided the other conditions remain constant, decrease in the water content of the leaf is accompanied by a reduction in the rate of transpiration. When, however, the leaves are brightly illuminated the rate of transpiration from the potassium starved leaves rises rapidly until it exceeds that from the leaves produced in the absence of calcium or in a "complete" culture. It appears therefore, that in bright light the loss of water from potassium starved leaves may be excessive as it is greater than the loss which occurs from leaves having a normally higher water content.

It has been shown that under certain conditions the rate of water loss from a leaf may increase though the water content has fallen slightly below its normal level so that there is actually a water deficit in the leaf. If this high rate of loss is continued then wilting of the leaf, or in severe cases a complete and rapid drying out of those regions of the leaf most exposed to drying conditions, may take place. Wilting of a leaf may occur when the water deficit amounts to less than one per cent. and it seems reasonable to suppose that the danger point would be reached more rapidly in a leaf which has a low water content, such as a leaf from the potassium starved plant, than in a leaf which has a high water content, namely a leaf produced on a tree receiving a complete culture solution or a solution deficient in calcium.

SUMMARY.

- (1) The effects of deficiency of potassium and calcium on the growth and development of young apples trees in sand cultures is described.
- (2) When potassium was deficient small leaves were produced which suffered extensively from leaf-scorch.
- (3) When calcium was deficient the leaves produced were considerably larger than those borne on trees which received a "complete" culture solution.

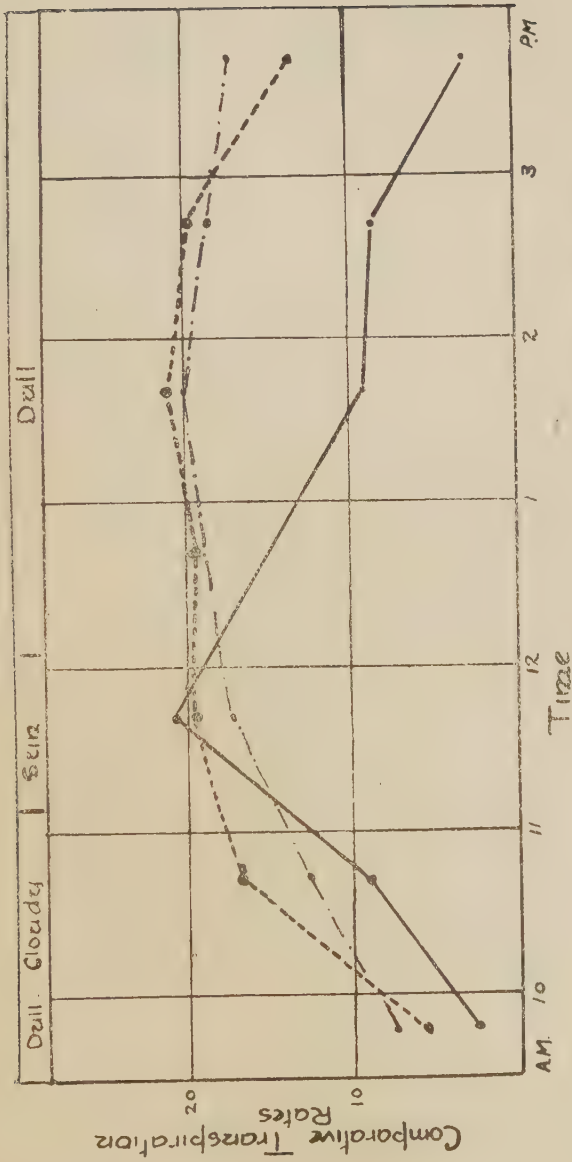


FIG. 1. Comparison of the transpiring power of the leaves of apple from three series of sand cultures. See page 42.

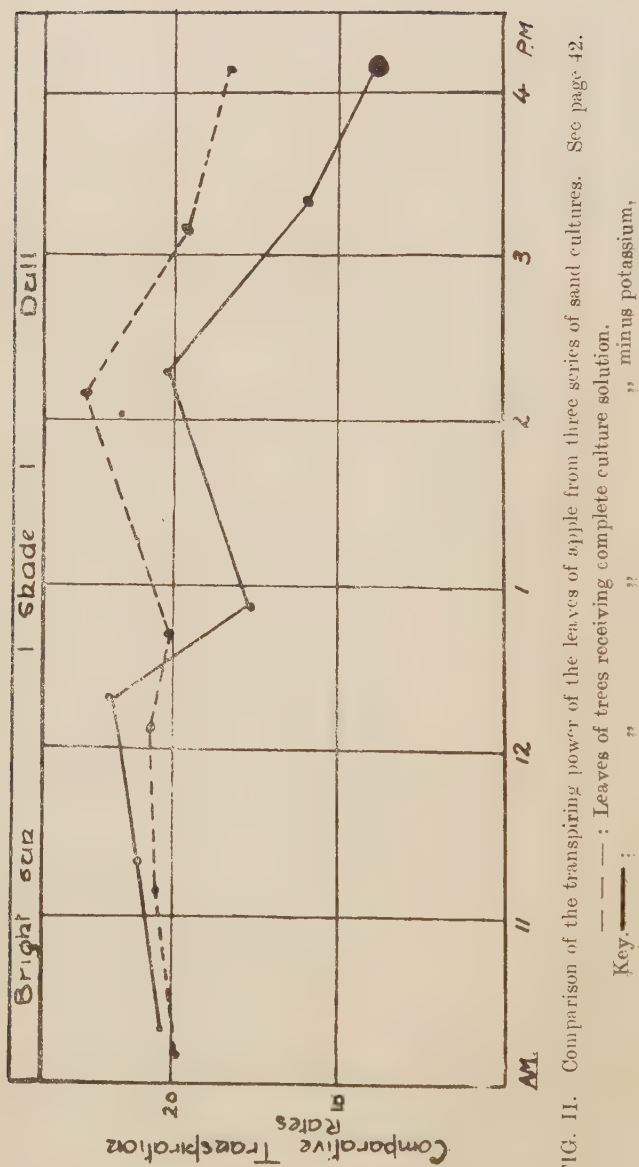


FIG. II. Comparison of the transpiring power of the leaves of apple from three series of sand cultures. See page 42.

- (4) Experiments on the leaves of gooseberry bushes growing in similar cultures showed :—
- (a) When potassium was deficient the leaves produced had a lower water-content than the leaves from bushes receiving a "complete" solution whilst when calcium was deficient the water content of the leaves produced was higher than that of leaves in the "complete" series.
 - (b) The power of the leaves to resist water loss was least in the potassium starved leaves and greatest in the calcium starved.
- (5) Preliminary experiments on the comparison of the transpiring power of the leaves of apple trees in sand cultures showed that under dull light conditions the rate of transpiration was lowest in the case of the potassium starved leaves. In bright sunlight the rate of transpiration from these leaves rose rapidly and was generally greater than that of the leaves of the other two series.

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THE TREATMENT OF SEEDLING APPLE TREES TO INDUCE EARLY FRUITING.

BY G. T. SPINKS.

One of the difficulties which confronts the breeder of new varieties of apples and other top fruits is the great length of time which usually elapses before a seedling plant begins to bear fruit. A seedling apple tree rarely, if ever, bears any fruit until it is about six years old, and frequently this length of time is prolonged to about ten years.

It is obviously desirable to shorten this period of unfruitfulness as much as possible, and this note is a record of some attempts to do this. Young apple seedlings always exhibit a definite "juvenile" habit of growth differing from the habit of an "adult" tree which has started bearing. Different seedlings naturally show differences in habit, but in general it may be said that they all show the following characters. The branches bear, often on the current year's wood, many lateral shoots, which are either long, thin and whippy, or are short and thin and almost spiny in character. Short lateral growths on the current year's wood are often terminated by thorns instead of buds. The leaves are small and the rosettes surrounding the terminal buds of short lateral growths, "lambourdes" and "dards," consist of few and small leaves which are evidently unable to supply enough nourishment to the bud to convert it into a fruit-bud.

The "juvenile" characters, of course, appear only on *seedling* trees and not on other young trees which consist of a stock on which has been worked a graft or bud taken from an "adult" tree. Apparently a seedling must grow out of its "juvenile" state before it commences to fruit, and the object of the experiments to be described was to find some method of shortening this "juvenile" period. Obviously an experiment of this sort cannot be conducted with any great accuracy, as all the seedlings used are distinct individuals and behave in different ways. An endeavour was made, however, to obtain some indication of the effect of different methods of treatment on the length of the "juvenile period." The methods adopted were some of those which are known to accelerate fruiting when used on ordinary varieties of apples which have passed out of their juvenile state.

PLAN OF EXPERIMENT.

The experiment was started on March 1st, 1921, by planting out 65 one-year old apple seedlings in the plantation. These trees were grown from seed of unknown parentage and were, in fact, simply a collection of seedlings such as are used as "free" stocks; but those used were all well-grown and as uniform as it was possible to obtain them. They were planted 15 feet apart in three long rows, the distance between the rows also being 15 feet. The trees were divided into groups of five and a different treatment was arranged for each group, as follows :—

- (1) No pruning; no treatment of any sort.
- (2) Shaping.
- (3) Shaping, ringing.
- (4) Shaping, root-pruning.
- (5) Shaping, manuring.
- (6) Shaping, manuring, ringing.
- (7) Shaping, manuring, root-pruning.
- (8) Light pruning.
- (9) Light pruning, ringing.
- (10) Light pruning, root-pruning.
- (11) Light pruning, manuring.
- (12) Light pruning, manuring, ringing.
- (13) Light pruning, manuring, root-pruning.

Some of the above terms need an explanation.

Control.

The trees in group (1) were simply allowed to grow naturally, without pruning or any manurial or other treatment, from the time they were planted as maidens.

Pruning.

"Shaping" indicates that the trees were pruned in Winter for two or three years after planting merely to train them into bush form; no other pruning was given to these trees.

"Light pruning" consisted of the above treatment and, in addition, cutting out inter-crossing branches and strong lateral shoots, and a light tipping of leaders. No spur-pruning was attempted and no summer pruning was done. No attempt was made to adhere to a rigid plan of pruning, as this would be useless when dealing with seedling trees which have all different characters. It was quite expected that any pruning would delay fruiting, but information was wanted regarding the amount of delay which would result from regulating the shape and size of the trees and the possibility of counteracting this delay by the other treatments given.

Manuring.

A mixture of artificial manures was applied to the trees in groups (5), (6), (7), (11), (12), and (13) in March or April of each year, except immediately after planting. The mixture consisted of sulphate of ammonia, sulphate of potash, and superphosphate in the proportions 2 : 2 : 5, and it was applied at the rate of 9 cwt. of the mixture per acre, *i.e.*, about $3\frac{1}{2}$ oz. per square yard. In 1922, 1 square yard round each tree was treated at this rate, in 1923, 4 square yards, and in 1924, 9 square yards.

Ringing.

The ringed trees were treated as follows :—

On May 16th, 1922, the main stem of each tree was given a ring consisting of a single knife cut extending down to the cambium all the way round the stem.

On July 4th, 1923, the main stem of each tree was again ringed, but in this case two knife cuts were made $\frac{1}{8}$ inch apart and the ring of bark between them was completely removed.

Root-pruning.

The trees to which this treatment had been allotted were root-pruned on November 25th, 1921, and December 18th, 1923, all roots being shortened to 9 to 12 inches on the second occasion.

Other Treatments.

In addition to the 65 trees given in the above list, 10 trees were used as scions for grafting, three scions being obtained from each tree. Ten scions, one from each tree, were head-worked on established bush trees, about 8 years old, which had been headed back. The remaining 20 scions were worked on Malling Type 9 stocks. The only stocks available were some which had only recently been planted, so that the scions had only a poor chance of making good growth.

A further five seedlings were planted in 8 inch pots in March, 1922, that is a year later than all the others, but as they were two years old when planted they are comparable with the other seedlings, which were only one year old when planted. These plants in pots were given liberal dressings each year of the same mixture of manures which was applied in the field, and they were lightly pruned.

DISCUSSION OF RESULTS.

It is not proposed to set out in detail the observations made on the various trees, but merely to give a summary of the results obtained. In October, 1924, when the trees were five years old it was seen that the result of the experiment was largely negative, in so far as up to that time no trees had produced flowers and there would apparently be no buds producing flowers in 1925.

Trees in the different groups, however, showed distinct differences which indicated which treatments had favoured the earliest fruiting.

The trees which had been *root-pruned* were on the whole smaller and growing less vigorously than any of the others. But this dwarfing effect had not been accompanied by any formation of flower buds or by any other signs of having reached the "adult" stage. On the contrary, all the trees were distinctly "juvenile" in habit, with the exception of four which showed slight traces of growing out of this condition. It was evident that the root-pruned trees would be the last of all to produce fruit.

The *ringed* trees showed the same characteristics as the root-pruned trees, but in a less marked degree. They were slightly less vigorous than the unringed trees. About six trees were definitely "juvenile" in character, eight were beginning to grow beyond that state, five were almost "adult" in appearance, and one was judged to be definitely "adult."

The trees receiving *no ringing* or *root-pruning* were the most vigorous, and of these three seemed to have reached the "adult" state, eight had nearly reached that state, while seven were still in the "juvenile" stage.

The *manuring* seemed to have produced slightly more vigorous trees, but the increase in vigour was not at all marked. The manured trees, on the average, were also more "adult," but here again the difference was small. On the whole, the more vigorous trees were also the more "adult" in character.

Pruning cannot be said to have had any consistent effect on the character of the trees, and certainly no significant difference between the shaped and pruned trees could be seen. During the short length of time for which the experiment was carried on it was really only in the last year that there was any inference in the treatment of these two sets of trees. The entirely unpruned trees varied considerably in the degree to which they had reached the "adult" state, and as there were so few of them it cannot be said with certainty that, on the average, they showed more or less of the "adult" character than the pruned trees. On the whole the trees which were manured and lightly pruned, but not otherwise treated, seemed to have made the best progress of any in the experiment, but this may be mere coincidence.

Trees *grafted* on Type 9 stock made very poor growth and were mostly juvenile in appearance, but they were grafted under such poor conditions that they cannot be said to have had a fair chance. In this connection another set of seedlings worked on dwarfing stocks may be mentioned, though they do not form a part of this experiment. In 1920 several hundred buds from young hybrid apple seedlings were worked on Mallings stocks, Types 4, 8 and 9, and in February, 1922, these were planted out here. None of these

trees have yet blossomed and very few show any fruit buds for 1925. Trees budded on similar stocks at the same time, the buds for which had been taken from seedlings already in the "adult" state, bore blossom when two years old.

The seedlings *headworked* on older trees have grown vigorously and most of them seem to have reached the "adult" state, but they have not flowered yet and show very few, if any, fruit buds for 1925.

The trees *in pots* are still entirely or partially "juvenile" in character and show no signs of flowering yet.

This experiment has now been concluded, as, although none of the trees have yet come into bearing, it was obvious that the special methods which were being tried were not having the desired effect.

SUMMARY.

From the above results it appears that any treatment which restricts growth, such as ringing, root-pruning, working on dwarfing stocks and growing in pots, does not induce earlier fruiting in very young seedlings. On the contrary it tends to keep the trees longer in a "juvenile" state and so delays fruiting. Probably the best way to obtain early fruiting is to encourage vigorous growth which will bring the tree to its "adult" state at the earliest possible date. When this state has been reached a tree which still refuses to bear can be brought into fruit by some such method as ringing; this method has actually been used with considerable success on "adult" but barren seedlings.

EGG-KILLING WASHES.

BY A. H. LEES, M.A.

Winter spraying of fruit trees has been a text book recommendation for a very large number of years, and the advice to do this operation has been given over and over again by those whose business it has been to advise the grower. It may be questioned, however, whether in most cases the giver of the advice had a clear idea of how any particular winter spray fluid worked. In most cases the cleansing of the trunks was emphasised and frequently claims for killing insect eggs were made. No one had, however, so far as the writer is aware, produced any proof of egg-killing powers of any winter wash.

In 1914 the writer referred to the then position of winter spray fluids (1) and certain mixtures were tried which, however, were not successful.

In 1915 (2) further trials were made which showed that hot water was impracticable, but that, with certain bleaching powder treatments, some success was obtained.

In 1917 and 1919 Peterson (3 and 4) working in U.S.A. published papers showing the effect of various sulphur washes and of crude carbolic acid on the eggs of apple aphids. He found that the higher concentrations of lime sulphur 1 in 6 and 1 in 9, gave good kills and he obtained promising results from the use of crude carbolic acid.

The results with lime sulphur appeared to warrant further trials of this substance in this country and various small trials were done by the writer, using this substance. It was very soon evident however, that sufficiently exact data could not be obtained by any field trial and accordingly, the method of trial on eggs of *Aphis pomi* on pot trees was started. Conditions could thus be much more effectively controlled while still leaving the eggs under an outside environment until hatching started. A few months before this conclusion was reached, Mr. S. P. Wiltshire, at that time Mycologist to the Research Station, brought back from Holland, during the summer of 1921, samples of a Dutch "Carbolineum" which had been giving consistently good results in that country. It was accordingly included in the 1921 trials a year before it was

introduced into this country as a commercial article. More recently several British forms of the tar distillate washes have appeared.

The following paper describes the results in the third season of testing egg-killing washes. Especial attention has been paid to the tar-distillate washes frequently sold with the prefix "carbo." An attempt has been made to form fluids with Cresylic Acid, a substance which in last year's trials gave excellent results. In addition, further tests have been made on Lime-Sulphur with a view of possibly confirming previous years' results.

PROCEDURE.

The eggs selected as a test were again those of the Permanent Apple Aphis. This is the only insect egg that can be obtained in sufficient quantity on a limited space. No other aphid eggs are suitable, as they are always laid in an isolated manner instead of in masses. Apple sucker and caterpillar eggs have a similar disadvantage.

I am much indebted to a well-known nurseryman for obtaining for me, apple plants well infested with eggs in a year in which such material was very difficult to find. These plants were ungrafted stocks of Malling Paradise types 2 and 5. As was to be expected, the type 2 specimens were considerably stronger than the type 5.

When received, the plants were potted up in ordinary potting soil and placed outside.

At various times during the winter, spray fluids were applied by means of a small hand spraying machine.

This work was done in a cold and airy greenhouse. The plants were allowed to dry and then placed outside exposed to all weather conditions. Shortly before hatching began they were taken under cover and placed horizontally over oiled paper.

Most of the young lice fall off under these conditions and are thus easily counted. Those that remained on the plant (as happens when a bud is showing green) were removed and counted. After hatching had finished the plants were cut into convenient lengths and submitted to hot 10% caustic soda for a short time.

This treatment loosened the eggs which were then carefully washed into another vessel and made up to 1,000 c.c. Aliquot portions of the agitated liquid were poured on to a petri dish and the contained eggs counted. The average of six countings gave the number of eggs present. A simple calculation from this gave the total estimated number of eggs on the particular plants.

CONTROLS.

Table 1 gives details of the controls. There were eight of type 5 and five of type 2. The lowest percentage hatch for type 5 was

4.3, the highest 16.1 and the average 10.6. The lowest for type 2 was 15.6, the highest 85.1 and the average 49.7. It is clear from these figures that the eggs on Type 2 were more viable. It is also clear from a consideration of the number of eggs present in each case that this number had nothing to do with the percentage hatch. Further evidence that the type influenced the percentage hatch is found in Tables 2—5. In these, where a strict comparison of treatments could be made, the average for the two types is shown.

Only in one case, A in Table 3, does type 5 give a higher figure 2.95 over type 2 with 1.03.

It would appear, therefore, from five different series, that the eggs on type 2 were more viable than those on type 5.

It has been pointed out previously that there is no correlation between the number of eggs used and the percentage hatch on the controls and this same absence of correlation can be seen in Tables 2—5.

There would appear therefore, to be only one conclusion, namely, that the stronger stock offered more food to the egg-laying female than the weaker and that in consequence her eggs were more viable.

This conclusion introduces a factor previously overlooked in egg-killing trials and serves to explain some of the discrepancies in the controls observed in previous years. It serves also to emphasise the writer's previous contention that unless an egg-killing wash gives a percentage of hatch of about one it is not likely to be very effective in practice.

LIME SULPHUR.

This fluid gave very encouraging results in the previous year's trials, especially where combined with a spreader. In order to obtain confirmation they were repeated in this year's trials. Three strengths were tried, one volume of concentrate in 15 volumes, one in twenty and one in thirty.

In one series these were combined with 1% calcium caseinate (1lb. per 100 gallons) as a spreader, in the other the lime sulphur was applied alone and each series was done twice, once in December and once in February. Table 2 contains the results. An inspection of the percentage hatch figures clearly shows that no effective egg-killing has been obtained except the 1 in 15 with caseinate done in December. This figure, however, is not supported by those for the other strengths (6.6-7.7). No improvement can be seen as the result of adding caseinate either in December or February. The figures for the December spraying are on the average, very much lower than those for the February spraying, but it would seem easier to attribute this to the influence of the weaker stocks (as shown by the controls) than to the time of application.

TABLE I.
CONTROLS.

Stock.	No. of Eggs Estimated.	Percentage Hatch.
MALLING PARADISE.— Type V.	1200	7.5
"	1150	16.1
"	560	13.2
"	693	15.2
"	420	5.5
"	446	13.0
"	616	9.9
"	2300	4.3
Average for Type V.		10.6
Type II.	320	15.6
"	773	48.8
"	983	48.1
"	660	85.1
"	480	50.9
Average for Type II.		49.7

TABLE II.
LIME-SULPHUR.

Stock.	Date of Application.	Strength.	With 1 % Ca. Caseinate	No. of Eggs Estimated.	Percentage Hatch.
V.	Dec. 21	1/15	Yes	1193	.92
	"	1/20	"	560	6.6
	"	1/30	"	700	7.7
	"	1/15	No	793	3.3
	"	1/20	"	700	3.4
	"	1/30	"	662	2.3
Average Type V.					3.88
II.	Feb. 29	1/15	Yes.	1283	25.9
	"	1/20	"	1733	35.4
	"	1/30	"	1380	29.5
	"	1/15	No.	480	25.9
	"	1/20	"	1733	53.4
	"	1/30	"	1933	30.2
Average Type II.					33.4
II.	Mar. 4	1/20	1% Sol. Casein	1516	14.0
	"	1/30	" " "	1200	20.7

TABLE III.
TAR DISTILLATES.

Stock	Spray.	Date of Application.	Strength Percentage.	No. of Eggs Estimated.	Percentage Hatch.
V.	B.	Dec. 21	10	1086	0.0
"	"	"	5	733	.4
"	"	"	$2\frac{1}{2}$	520	1.7
"	"	"	1	906	2.0
Average Type V. B.					1.03
II.	B.	Feb. 20	10	3300	.6
"	"	"	5	1080	2.98
"	"	"	$2\frac{1}{2}$	1233	9.5
"	"	"	1	2416	13.5
Average Type II.					6.63
V.	A. (Old)	Dec. 21	4	340	3.0
"	A. (Fresh)	"	4	1086	3.9
"	" "	"	2	253	2.0
Average Type V. A. (Fresh)					2.95
II.	A. (Fresh)	Feb. 11	4	746	.67
"	" "	"	2	4700	1.4
Average Type II.A. (Fresh)					1.03
V.	C.	Jan. 8	10	2100	0.0
"	"	"	5	1080	.55
"	"	"	$2\frac{1}{2}$	1500	3.0
"	"	"	1	70	27.0
II.	D.	" 17	10	2116	.14
"	"	"	5	4066	1.2
"	"	"	$2\frac{1}{2}$	880	2.4
"	E.	"	1	1243	12.7
"	"	Feb. 20	10	3066	6.1
"	"	"	5	1120	22.0
"	"	"	$2\frac{1}{2}$	1000	27.2
"	"	"	1	3616	39.5

TABLE IV.
CRESYLIC ACID MIXTURES.

Stock.	Mixture.	Percentage Cresylic.	Date of Application.	No. of Eggs Estimated.	Percentage. Hatch.
V.	Cresylic, soap	8	Dec. 22	516	14.9
"	" "	4	"	1016	7.2
"	" "	2	"	1086	10.5
"	" "	1	"	870	10.7
"	Cres. soap, casein	8	"	980	3.2
"	" "	4	"	640	6.1
"	" " "	2	"	1086	33.5
"	" " "	1	"	713	6.9
Average Type V.					11.6
II.	Cresylic, soap.	8	Feb. 11		16.1
"	" "	4	"	1633	8.6
"	" "	2	"	2266	25.2
"	" "	1	"	276	7.2
"	Cres., soap, casein	8	"	3666	22.1
"	" "	4	"	460	47.4
"	" " "	2	"	563	35.3
"	" " "	1	"	1766	32.5
Average Type II.					24.6
V.	Cres. soap, Red Oil	4	Dec. 22	633	6.0
"	" " " "	3	"	460	2.4
"	" " " "	2	"	1150	3.4
"	" " " "	1.3	"	320	5.0
II.	" " " "	4	Feb. 11	270	34.8
"	" " " "	2.6	"	1366	7.1
"	" " " "	1.2	"	1283	76.0

TABLE V.
CRESYLIC ACID DUSTS.

Type.	Mixture.	Date of Applctn.	No. of Eggs Estimated.	Percentage Hatch.
V.	Lime 6gr., Cres. lcc., Caseinate lgr.	Jan. 8	1383	5.8
"	" 12gr., " lcc., " lgr.	"	420	8.8
"	" 24gr., " lcc., " lgr.	"	464	24.8
"	Gr.S. 10gr., " lcc., " lgr.	"	1383	8.7
"	" 20gr., " lcc., " lgr.	"	493	21.6
"	" 40gr., " lcc., " lgr.	"	1346	8.4
Average Type V.				13.0
II.	Lime 6gr., Cres. lcc., Caseinate lgr.	Jan. 17	1100	35.0
"	" 12gr., " lcc., " lgr.	"	260	29.2
"	" 24gr., " lcc., " lgr.	"	3032	13.7
"	Gr.S. 10gr., " lcc., Caseinate lgr.	"	540	15.5
"	" 20gr., " lcc., " lgr.	"	600	9.6
"	" 40gr., " lcc., " lgr.	"	1933	13.7
Average Type II.				19.4
V.	Lime 6gr., Cres. lcc.	Jan. 8	760	8.0
"	" 12gr., " lcc.	"	753	28.4
"	" 24gr., " lcc.	"	413	25.4
"	Gr.S. 10gr., " lcc.	"	626	6.5
"	" 20gr., " lcc.	"	640	12.2
"	" 40gr., " lcc.	"	840	30.7

Cres.=Cresylic Acid. Gr.=Grams, Caseinate=Calcium Caseinate,
Gr.S.=Green Sulphur.

Lime sulphur made up with 1% "soluble casein," a proprietary spreader with improved properties, also failed to show definite egg-killing powers.

The difference between the results obtained last season and this as regards lime sulphur are surprising and to the writer unaccountable. It is evident, however, that for the present lime sulphur must be regarded as an unreliable egg-killing wash, and in view of the continued success from tar distillate washes it would be advisable to discontinue its use against insect eggs during the winter except in special instances.

TAR DISTILLATE WASHES.

Since the trials of last year several new washes of British manufacture have appeared on the market. Though these washes are all of a proprietary nature it was thought desirable to obtain some information as to their efficacy as egg-killers. The information does not admit of publication under specific names and accordingly they have been assigned letters. The trials have, however, been fully justified, partly on the score of the many enquiries subsequently answered as to their action, and partly because they have shown that not every such material, though indistinguishable by the eye, has definite egg-killing properties.

In Table 3 will be found the results of these trials. They were designed to test the effect of different strengths and times of application and also of the different brands.

In one case the effect of fresh material was tried against material kept for two years in the laboratory in a half empty but stoppered bottle.

As regards the effect of strengths it is noticeable that in every case, with the exception of A tried in December, the higher strength gave a less percentage hatch than the lower. The divergence in this exception is not marked, and the method may therefore be considered a reliable one and sufficiently accurate to give the difference produced by a 2% difference in strength. The writer claims that no such accuracy can be obtained by field trials.

It was not possible to test early and late spraying except in two instances A and B as supplies of the others did not come to hand in time. At first sight the results from B seemed to suggest that the December application was much more effective than the February.

For each strength a lower percentage hatch was obtained for the December application. A careful consideration of the controls, however, combined with the comparative results set out in Table 2, and 5 suggest that the real explanation is the smaller viability of the eggs on paradise stock type 5. It was merely a coincidence that

the weaker stock was used in the December trials and the stronger in the February ones.

The case of A is suggestive. Here the February results were slightly superior, with an average of 1.03% hatch against 2.95. The effect of the stronger type 2 was here masked presumably by the greater effectiveness of the later spray. It is clear, therefore, that until further trials are made it is impossible to state whether the early or the late spray is the more effective.

Of the five brands tested A—D inclusive gave satisfactory kills for 4% or 5% and 10% strengths, but E was useless at any strength. On type 5, C and B gave almost identical figures while on type 2, D was rather superior to B.

The only case where fresh material was compared with stale (A) there was no material difference.

: CRESYLIC ACID MIXTURES.

Small trials from the previous year had shown that commercial Cresylic Acid made up as a very unstable emulsion at strengths of $2\frac{1}{2}\%$, $3\frac{1}{2}\%$ and 5% was very toxic to eggs of a A pomi.

A considerable extended series, Table 4, was tried this year, using this substance boiled up with soap in which it dissolves.

In some trials casein was added as a further emulsifier and in others the soap cresylic was added to commercial "red oil" to test the possibilities of a combined wash, as "red oil" is effective against Woolley Aphis and possibly against Mussel Scale.

None of the mixtures or strengths used, however, gave results justifying commercial usage, though the effect of the two paradise stocks was evident here as in all the other strictly comparable treatments. It was somewhat surprising that so great a strength as 8% cresylic failed to show definite toxic effects, whereas in the previous season's trials $2\frac{1}{2}\%$ showed a marked one. The only difference between the two trials was that in the first the cresylic acid was loosely held in combination and in the second firmly. It is possible that in this case the soap buffered the action of an otherwise toxic body and suggests that in tar distillate washes the methods of manufacture may be as important as the constitution. It at any rate confirms the view expressed by chemists writing on these washes that the manufacture is a delicate business requiring great care. In the writer's opinion the preparation of such washes by the grower is at present inadvisable.

CRESYLIC ACID DUSTS.

It was thought possible that if commercial cresylic acid was really toxic it might be combined as a dust in order to admit of more easy application than as a spray. Accordingly various

trials were made combining the substance with either lime or green sulphur as a carrier and calcium caseinate as a sticker.

The results are given in Table 5. The percentage hatch figures show that in no case were any striking results obtained and the figures are so erratic that no conclusion can be drawn between different strengths. Here, as elsewhere, the difference between the viability of eggs on types 2 and 5 is disclosed.

SUMMARY AND CONCLUSIONS.

1.—This paper describes the results obtained by the application of certain spray fluids on the eggs of *Aphis Pomi*, the Permanent Apple Aphis.

2.—Both in the controls and in every other comparable case the eggs laid on Malling type 2 stocks proved more viable than those on Malling type 5.

3. Lime Sulphur at all strengths tried with or without calcium caseinate failed to show definite egg-killing power.

4.—Tar distillate washes gave generally good results and the method of testing is accurate enough to show the effect of a difference in strength of wash applied of 2%.

5.—It was not possible to state whether early or late applications of tar distillate washes is the more effective owing to the apparent difference of viability of eggs in the two series.

6.—Commercial cresylic acid, whether made up with soap as a wet spray or with dry carriers as a dust, failed to show egg-killing power.

PLUM APHIS AND BROWN ROT CONTROL.

BY A. H. LEES AND H. R. BRITON-JONES.

INTRODUCTION.

In the constant effort to produce crops of greater quantity and high quality the fruit grower is face to face with the urgent necessity of controlling parasites. These parasites may be entomological and mycological, and it has been the object of applied research to work out methods suitable for the control of all the possible pests and diseases. This work has resulted in a larger number of separate control measures adopted in most cases to particular pests and diseases only and these recommendations can be found in textbooks and similar sources of information. It might well be asked, however, whether some of these recommendations with their numerous spraying for maladies could ever be carried out without the grower becoming bankrupt in the process and the question becomes more acute still when not one but several maladies have to be controlled at the same time.

The writers feel that the view point already taken by some workers that the proper criterion of disease control is the net profit accruing to the grower is the correct one. The problem is, after all, the grower's and not primarily the plant pathologist's, and there is obviously an economic limit to the number of treatments that a grower can apply to a crop plant no matter how many maladies are affecting it. In extreme cases it may be even more profitable to destroy the crop plant rather than to attempt to control disease by repeated costly treatments. With these considerations the writers have approached the question of control of plum maladies and have endeavoured to find out by the series of experiments about to be described single treatments that would give the highest possible control of the commonest and most important troubles of plum trees in general.

DESCRIPTION OF EXPERIMENT.

It was originally intended to select an orchard where both Aphis and Brown Rot might reasonably be expected to develop. Fortunately sufficient winter moth caterpillar appeared to give data as regards control of this pest also.

PLAN DIAGRAM.

Treatment.		Date of Application.	Position and Number of Trees.			
I.	Carbo fluid 7 per cent. ..	31/1/24	1-12	95-106	191-202	287-298
II.	Lime Sulphur 1.15 +Ca. Caseinate .2 per cent.	7/3/24	13-24	107-118	203-214	299-310
III.	Lime Sulphur 1.30 +Ca. Caseinate .2 per cent.	7/3/24	25-36	119-130	215-226	311-322
IV.	Caustic Soda 10 lbs.+ Liquid Soap, 3 galls.+ Water 100 galls.	3/4/24	37-48	131-142 167-178	227-238	323-334 Not sprayed. Used as Control
V.	Caustic Soda 10 lbs.+ Liq. Soap 3 galls.+Paraffin 1 gall.+Water 100 galls.	4/4/24	49-60	143-154	239-250	335-346 Not sprayed. Used as Control
VI.	Caustic Soda 10 lbs.+ Liq. Soap 3 galls.+ Nicotine 8 ozs.+Water 100 galls.	5/4/24	61-72	155-166	251-262	347-358 Not sprayed. Used as Control
VII.	Control (Untreated) ..		73-84	167-178 (see above)	263-274	359-370
VIII.	Carbo fluid 4 per cent. ..	31/1/24	85-94	179-190	275-286	371-378

Thus the orchard proved to contain the three chief troubles of the plum. The writers are, of course, well aware that other troubles do occur, but they contend that such are not of sufficient frequency to warrant inclusion in a regular spray programme.

The orchard selected for the trial was situated in Gloucestershire and occupied about 7 acres. About one third was interplanted with black currants. The trees were tall half standards of the varieties Victoria and Purple Pershore and, apart from the disease present, were well grown specimens. They had suffered severely from Brown Rot during the previous year and events proved that both aphid and winter moth eggs were present in sufficient numbers to give data on these two pests also.

The plan diagram shows the lay out of the experiments as decided upon in the first instance and the slight modifications which had to be made owing to the danger of injury to an intercrop of black currants in one half of the plantation. The question of intercrops is again referred to overleaf.

RESULTS.

The following table shows the results of the spraying in regard to their effectiveness against Aphid, Brown Rot, and Caterpillar damage.

Treatment.	Aphid Control	Brown Rot Control.	Caterpillar Control.
I. 7 per cent. Carbo	Complete	Complete	Fairly good
II. L. S. 1 : 15	Very slight	Slight	Very slight
III. L. S. 1 : 30	do.	Very slight	do.
IV. Caustic + Soap	Complete	Slight	Complete
V. do. + Paraffin	do.	do.	do.
VI. do. + Nicotine	do.	do.	do.
VII. Control (No treatment)	Relatively bad attack	Relatively bad attack	Moderately bad attack
VIII. 4 per cent. Carbo	Complete	Fairly good	Fairly good

It will be seen that none of the spraying materials used completely controlled Aphid, Brown Rot and Caterpillar. The results which were recorded on 22, 5, 24 can be summarised as follows :—

Lime Sulphur Washes.

Of the two strengths used, the stronger was slightly the better, being a little more effective against Brown Rot. Lime Sulphur partially controlled all three maladies, but it was felt that the benefit derived was not sufficient to justify recommending its use against all or any of the troubles concerned.

Caustic Washes.

The results were the same for all three and as far as could be observed nothing was gained by adding either Nicotine or Paraffin

to the Caustic Soda and Soft Soap solution. All three were highly satisfactory against Aphis and Caterpillar, but their action on Brown Rot disease was only slight. The effectiveness of these washes against Aphis and Caterpillar might be due to the fact that they were applied later in the season than the other sprays and killed newly hatched insects.

Carbo fluids.

The higher strength (7 per cent.) completely controlled Aphis and Brown Rot and was also fairly effective against Caterpillar. The lower strength (4 per cent.) gave somewhat similar results except that it was not quite so satisfactory against the Brown Rot. This might be due to the fact that the trees sprayed were very seriously attacked by Brown Rot in the previous year and it required the stronger concentration under such conditions. The only sign of Brown Rot on trees sprayed with 7 per cent. Carbo fluid were a few pustules which had developed subsequent to spraying on dead twigs killed by the previous year's attack.

DISCUSSION.

The wood killed in the previous year had not been removed and there was a very considerable amount of it on all the trees. The trees were of the standard type and were from twelve to sixteen years old. It has been recommended to cut out all dead branches and twigs as a supplementary measure against Brown Rot. This operation is extremely sound and should always be done in gardens or small plantations. It is felt, however, that it is impracticable in large commercial plantations of fully grown standards trees owing to the difficulty of recognising from the ground the smaller dead twigs and the cost of labour of such an operation, if done when the trees are in a dormant stage.

It is felt that the most satisfactory method of dealing with these three troubles would be to spray first with 7 per cent. Carbo fluid as well as apply grease bands to the tree trunks. These two operations will satisfactorily control all three. Later in the spring when the trees are in leaf the larger dead branches can be more easily recognised and can be removed more effectively, more quickly, and consequently with much less cost in labour to the grower. In subsequent years the application of 4 per cent strength of Carbo fluid, and grease bands would effectively control all three when used on trees which were moderately clean to start with. The use of the weaker strength would almost halve the cost of the spraying fluid which in large plantations would be very considerable. This treatment, though applicable to standard orchards in general, admits of certain exceptions in special cases. Thus in the case of young orchards where straight growth is essential and where for

the first few years after planting grease banding is relatively laborious and arsenate spraying relatively easy arsenate can be used for the control of Tortrix moth. In older orchards where straight growth is not so essential, the framework having been formed already, grease banding may be done instead of arsenate spraying. Spraying could be further reduced though at some risk by omitting non-susceptible trees from the yearly programme.

There is a further advantage in using the Carbo fluid, which is applied when the tree is still dormant and when such intercrops as Black Currants, Gooseberries, Red Currants, etc., are also dormant. In this case there is no danger of any damage to these intercrops. The caustic washes are applied later, just when the plum buds are about to open, at which time there is danger of damage to the intercrops which are then in leaf.

Having come to the conclusion that the Carbo fluid was the most satisfactory remedy, it is intended this year to test out different brands of Carbo fluids at different strengths with a view not only to find out which is the best product on the market but also to strike as nearly as possible the economic balance of cost and efficacy by reducing the strength as far as possible.

In conclusion, we wish to express our indebtedness to Mr. A. McKibbin, of Kents Green, Taynton, Glos., for putting his orchard at our disposal for the trial, and for extending to us his whole-hearted co-operation and hospitality.

PROGRESS REPORT ON RED PLANT OF STRAWBERRIES.

BY A. H. LEES AND L. N. STANILAND.

In the Annual Report for 1923 Ballard and Peren set out the correlation of Red Plant with Cauliflower Disease. They claimed that the two were manifestations of one and the same disease, the difference being caused by different types of re-action on the part of the plant, and that the infecting organism was the eelworm (*Aphelenchus fragariæ*). In their descriptions they state that *A. fragariæ* "can usually be found in the growing points of 'Red Plants' and often in the growing point of runners on 'Red Plants.' " They further state that they found it in "Small Leaf" plants, but do not mention its presence in other types nor in normal plants. Subsequent examination on the part of the present writers has shown that in the summer and autumn of 1924 the eelworm could be found in comparatively large numbers in normal plants. These plants appeared perfectly healthy and there was no sign whatever of any resemblance to typical "Red Plant." This discovery made it necessary to revise the current conception of the relation of eelworm to red plant, since it was evident that the mere presence of *A. fragariæ* was not sufficient to cause disease. It was clear that not only might different manifestations be produced by different re-actions on the part of the plant, but that even no manifestations at all might follow.

The position was therefore still obscure and it became increasingly obvious that it was necessary to collect further experimental data before observed facts could be explained. As many plants as possible were examined during the summer and autumn of 1924 and the results are given below.

Facts derived from observation in 1924.

(1) Presence of Eelworm (*A. fragariæ*) in normal plants.

Contrary to expectation it was comparatively easy to find eelworms in the leaf bases of normal plants. Such plants have been found in Somerset, Herefordshire, Worcestershire and Hampshire, and may, therefore, be regarded as probably of general distribution.

(2) Position of Eelworm.

From June to the end of September they were found abundantly in the leaf bases. They are found with their heads in the superficial tissue of the inner (upper) surface of the leaf base close to the axil. They could not be found in the mesophyll.

From about the beginning of October till the time of writing (November), they have been found in the growing points, though it is only some growing points of a "Red Plant" that are attacked. Frequently the attack has been intense enough to kill the growing point and thus to cause stimulation of lateral growing points. This would appear to be the first stage—the production of the typical open crown "Red Plants." A further killing out of these lateral growing points may explain the origin of the "patch plant" type. In the summer the growing point is only rarely attacked except in the case of "cauliflower" plants, when the growing point is usually hypertrophied. In normal plants eelworm has not been found in the growing points either in summer or autumn, though at this latter season the numbers in the leaf bases is very much reduced.

Aphelenchus may be found in fair percentage in runners in the summer, but are rarely inside the bud; "cauliflower" runners, however, can and have occurred, but as far as is known these cannot be produced unless eelworm is present near the growing point. First runner plants (*i.e.*, those produced first on a runner) are, on the average, more highly infected than those runner plants produced later; cases have occurred where infection has taken place in the sixth runner plant, this being some distance away from the parent. It is extremely difficult to decide from ordinary observation in the field, whether a runner contains eelworm or not, and it has been found that a careful examination in the laboratory is necessary.

Influence of Moisture on the Eelworm.

It has been observed in the field, both in the strawberry growing districts of the Bristol Province and at Long Ashton, that in those areas of a strawberry field where there is much waterlogging red plant is more noticeable. The reason for this is not known at present, but eelworm has shown itself to be very susceptible to moisture under laboratory conditions. In cases where plants have been sent in for examination it has often been found that eelworm cannot easily be found unless the plant for examination is kept in a moist atmosphere for some hours. It should be mentioned that the methods used for finding eelworm are as follows. The leaf bases are placed in watch-glasses with a little water and allowed to stand for about five minutes. Eelworm may then be observed free in the water. It is preferable that the leaf bases be washed thoroughly, with the same water into the same watch-glass,

by means of a pipette so as to be sure of obtaining the full number of eelworms. To examine a growing point the material is placed on a glass slide with a drop of water and teased apart with needles.

If the plant is not kept for some hours in a bell-jar over a plate containing a little water, it is often found that few eelworms are obtained. A plant fresh from the field does not need to be so treated. The current year has been a very wet one and it is interesting to note that eelworm, and plants suffering from "Red Plant" and "Cauliflower" symptoms, have been exceptionally abundant.

A preliminary experiment has been carried out to ascertain the possible effect of rain on the number of eelworms present in a plant. Seven crowns from bad cases of "Red Plant" were placed in a fine sieve in the bottom of which was a layer of coarse sand an inch deep; the sieve was then placed for half-an-hour in artificial rain, which was comparable to a shower of medium severity. The sand was gently shaken up, a little at a time, with water, which was pipetted off and examined for eelworm as soon as the majority of the sand had settled; in this way all the sand was examined and the number of eelworms washed out of the seven crowns determined. The number was found to be 32, an average of between three and four from each crown. *Aphelenchus* was present as well as other possibly saprophytic kinds.

Assuming that eelworm may be washed out of strawberry plants by rain at any time of the year, it would seem that the rate of production must be sufficiently high to allow for their continuous presence on the plant despite the washing out thus caused. At the end of September the number of eelworms in the outer leaf bases dropped considerably, this being, perhaps, accounted for by assuming that the rate of reproduction has fallen, the washing out of eelworm now producing a definite reduction in numbers. Little, however, is known about of life history, the egg stage not having been found as yet. From May up to the time of writing (Nov.), individuals of all sizes are constantly found, which suggests constant breeding throughout the period mentioned. It is probable, however, that breeding slackens towards the winter, since fewer are found in the leaf bases. The washing out by rain continued right up to the time of decrease of eelworm in the leaf bases, so that this decrease must mean a slackening in reproduction.

These facts suggest a distribution of eelworm other than that hitherto accepted.

For an explanation of the different manifestations of the disease, other factors must also be investigated. The writers still accept the presence of eelworm as a necessary hypothesis for the moment, but suggest that its presence alone is not sufficient.

It would be premature at this stage to elaborate the various possible factors that may be involved, but trials have been started to test such possibilities as place of infection (leaf base or growing point), amount of dose and the state of the plant, whether strong growing or checked through any cause. It is hoped that these trials may throw some light on the field observations that have been made by the various workers engaged on this problem.

SOME INVESTIGATIONS ON THE BOTTLING OF CIDER.

BY B. T. P. BARKER AND OTTO GROVE.

One of the leading features of the modern development of the cider industry is the increased demand for bottled cider. While it is not suggested that the consumption of cider direct from the wood will be entirely displaced, the trade in cider in bottle presents greater commercial opportunities and is, in many respects, more suited to the character of the beverage. As the consumption of cider extends in districts outside the centres of production and as the export trade develops—two features which have already been very marked during recent years—it becomes increasingly evident that the industry will rely very largely on the bottled trade for future progress.

The drawbacks to cider in cask for domestic consumption are familiar. The relatively weak alcoholic strength of the beverage in conjunction with the almost invariable presence of unfermented sugar renders it unstable in character and peculiarly susceptible to various bacterial disorders on access of air. Thus, unless some preservative is used—a practice which is open to obvious objection—deterioration begins to set in as soon as a cask is tapped. That is a matter of every-day experience : what has not been so generally recognised hitherto, and what the experiments about to be recorded show, is that even when the cask is kept filled and securely bunged deterioration also occurs, although not to the same extent.

Cider in bottle on the other hand is relatively stable. Air is completely excluded and loss of quality due to its action is reduced to a minimum. Bottled cider can thus be kept in the average case for an indefinite time without serious deterioration. On that account it is obviously more suited for domestic use and for purposes where its consumption is irregular.

Notwithstanding the relative stability of cider in bottle, the results are far from consistent, as every bottler knows. Sometimes too heavy a deposit is formed : on other occasions there is little deposit but a considerable development of “fliers,” the latter name being commonly used to describe the loose stringy growths composed

mainly of aggregates of acetic bacteria. Frequently an excess of gas is produced, leading at times to the bursting of the bottles: at other times the liquor fails to develop the least sparkle. Occasionally the onset of bacterial disorders, *e.g.*, cider sickness, ruins whole batches of bottled stock.

The bottling of ciders, therefore, presents many problems, most of which have hitherto not been closely investigated. The following account of some experiments on the subject, conducted during the last few years at Long Ashton, will serve to show its vital importance to the cider industry and the necessity of giving serious consideration to the methods of storage of cider in bulk.

Before describing the experiments it may be added that many of the difficulties incident to the practice of bottling cider are avoidable, if pasteurisation after bottling and conditioning is adopted. Recent Reports of the Institute record results fairly satisfactory and reliable for commercial purposes, but the superior quality of a perfectly sound cider naturally conditioned cannot be gainsaid.

The objects of the preliminary investigations were (*a*) to compare the behaviour and changes in composition of a wide range of ciders of different types after bottling; (*b*) to examine the influence of the time of bottling upon subsequent behaviour in bottle, especially in relation to the storage conditions of the cider prior to bottling; and (*c*) to trace the nature of the relationship, if any, between the natural rate of fermentation of a cider and the time at which it can be bottled to best advantage.

Information on these points was needed before the problems of bottling could be more closely attacked.

It may be well at this point to state that the writers' experience in the bottling of ciders, which now extends over many years, has satisfied them that for any given sample of cider there is a point of time for bottling in its life when it will give the best results. If bottled before that point has arrived, the tendency will be for excessive fermentation and deposit in bottle; if bottling is deferred after that period, the longer the delay in bottling the greater will be the difficulty of developing natural condition in bottle and the more troublesome the development of "fliers." These conclusions apply primarily to straightforward cases of bottling, in which cider taken direct from the cask is used and no preliminary or incidental treatment, such as carbonation, is resorted to. Any special treatment of that kind introduces complicating factors which it is desirable to eliminate in a preliminary investigation. The whole of the work here considered has therefore been conducted with ciders bottled direct from the storage vessel.

A. THE NATURE OF THE CHANGES IN BOTTLED CIDERS.

As a starting point for further study the behaviour of a series of ciders varying widely in character and composition was closely watched for several months after bottling. The ciders selected for observation were made from different varieties of apples during the autumn of 1921 and were bottled in each case on the same date, viz., March 9th, 1922. The following Table I shows the analysis of the freshly pressed juice, the dates of making and filtration and the chemical composition at the time of bottling and at the date of the latest examination at the beginning of January, 1923, some ten months after bottling. It should be stated that no attempt was made in these preliminary tests to secure complete chemical data or to aim at anything closer than approximate accuracy in the determination of the amounts of the various constituents. A more detailed examination in certain directions will be desirable in later stages of the investigations, but the time available during the season's work did not permit of anything more elaborate than the simple routine methods of determination for cider-house purposes being used. These are admittedly open to criticism but suffice to provide the information being sought in the first instance.

Dealing in turn with the respective characters of which estimation was made, the specific gravity change—which represents primarily loss of sugars by fermentation—was in most cases insignificant, a drop of one point only being shown. The Crimson King, Kingston Black and Royal Wilding samples alone showed more and the maximum of these was limited to a three-points fall. There is little doubt that in the case of Crimson King the high rate of fermentation prior to filtration was associated with the amount of fermentation in bottle, but this does not apply to the other two. The fall in the Kingston Black gravity was accompanied by a relatively large reduction in acidity—from .58 per cent. to .43 per cent.—and, since bacterial action is suspected as being responsible for the latter, it is more than likely that it, rather than alcoholic fermentation by yeasts, caused the major portion of the gravity loss.

The changes in acidity after bottling, as indicated by the titration method, were relatively much more marked. In all cases the total acid content showed diminution. The smaller changes of the order of .03 or .04 per cent., or less, have possibly no special significance. Any tendency to increase by the formation of volatile acids might well be offset by the production of esters. But the larger losses, such as those of .18 per cent. by Crimson King, .23 per cent. by Redstreak, and .15 per cent. by Kingston Black, suggest, as already mentioned for the latter in the previous paragraph, the action of acid-destroying bacteria. In this connection it is

TABLE I.

	Rate of fermentation of juice at 25° C.	Specific Gravity.				
		At milling.	At filtration.	At bottling Mar. 9, 1922.	After 10 months in bottle Jan., 1923.	
Backwell Red ..	5.5	1.054 (Oct. 14)	1.031 (Nov. 8)	1.026	1.025	
Butter Box ..	4.7	1.055 (Oct. 20)	1.032 (Nov. 15)	1.020	1.019	
Crimson King ..	11.0	1.071 (Nov. 22)	1.023 (Jan. 3)	1.016	1.013	
New Foxwhelp ..	3.8	1.055 (Oct. 14)	1.035 (Nov. 21)	1.021	1.020	
Redstreak ..	2.5	1.050 (Nov. 16)	1.031 (Jan. 4)	1.023	1.022	
Kingston Black..	3.4	1.062 (Nov. 1)	1.035 (Jan. 30)	1.030	1.027	
Royal Wilding ..	4.6	1.061 (Nov. 15)	1.034 (Feb. 1)	1.027	1.025	
Yarlington Mill	3.0	1.048 (Nov. 30)	1.019 (Dec. 29)	1.007	1.007	
Broadleaf Norman	4.0	1.055 (Nov. 10)	1.020 (Jan. 3)	1.006	1.006	
Handsome Normn.	5.3	1.060 (Nov. 15)	1.028 (Jan. 30)	1.012	1.011	
Mixed fruit ..	6.8	1.050 (Oct. 19)	1.030 (Nov. 11)	1.020	1.019	

	Acidity. (per cent. as malic acid)			Tannin per cent.		
	At milling	At bottling Mar. 9, 1922.	After 10 months in bottle Jan., 1923.	At milling.	At bottling Mar. 9, 1922.	After 10 months in bottle Jan., 1923.
Backwell Red ..	0.68	0.45	0.42	0.10	0.08	0.08
Butter Box ..	0.72	0.47	0.45	0.12	0.11	0.10
Crimson King ..	0.88	0.76	0.58	0.15	0.15	0.13
New Foxwhelp ..	1.02	0.81	0.67	0.18	0.15	0.15
Redstreak ..	0.49	0.55	0.32	0.13	0.11	0.11
Kingston Black ..	0.55	0.58	0.43	0.19	0.17	0.16
Royal Wilding ..	0.32	0.34	0.32	0.20	0.20	0.20
Yarlington Mill ..	0.39	0.40	0.36	0.25	0.24	0.23
Broadleaf Norman	0.36	0.40	0.38	0.22	0.22	0.17
Handsome Norman	0.25	0.32	0.30	0.21	0.19	0.17
Mixed fruit ..	0.46	0.39	0.33	0.11	0.11	0.10

	Alcohol precipitate per cent.		Colour index figures.	
	At bottling Mar. 9, 1922	After 10 months in bottle Jan., 1923	At bottling Mar. 9, 1922	After 10 months in bottle Jan., 1923
Backwell Red ..	0.55	0.58	0.6	0.4
Butter Box ..	0.23	0.29	0.6	0.5
Crimson King ..	0.29	0.36	1.0	0.7
New Foxwhelp ..	0.29	0.22	0.9	0.7
Redstreak ..	0.80	0.72	1.1	0.6
Kingston Black ..	0.25	0.24	2.5	2.4
Royal Wilding ..	0.40	0.38	1.9	1.1
Yarlington Mill ..	0.42	0.40	1.3	0.6
Broadleaf Norman	0.19	0.28	1.8	0.9
Handsome Norman	0.20	0.23	1.5	0.8
Mixed fruit ..	0.42	0.48	1.2	0.7

interesting to note the changes in acidity between the freshly pressed juices and the ciders at time of bottling. Each of the ciders of relatively high initial acidity, *i.e.*, .6 per cent. and upwards, show considerable diminution of total acid content by the time of bottling. Two of the three ciders with medium initial acidity, *viz.*, Kingston Black and Redstreak, show a slight rise in acidity by that time, the third, made from mixed fruit showing a slight fall. The remainder, of the low-acid-type, show a slight increase over the same period. These indications suggest that the more acid juices are liable under proper conditions for cider-making to suffer more from the action of acid-destroying bacteria than from that of organisms producing volatile acids, *e.g.*, the acetic bacteria. while the reverse applies to low-acid juices.

The "tannin" contents after bottling appear to undergo practically no change that is registered by the method of analysis. The fresh juice in most cases shows a slightly higher amount, the reduction by bottling time being probably attributable to oxidation.

The figures for the alcohol precipitate were obtained by weighing the amount of dried precipitate produced on addition of two volumes of absolute alcohol to one volume of cider. This precipitate consisted mainly of pectic substances. Its amount shows no great or regular difference during the period in bottle, the only noteworthy case being that of Broadleaf Norman, in which there was a rise from .18 to .28 per cent. It would seem, therefore, that some abnormal change had occurred in the latter, possibly the formation of alcohol-insoluble material from the sugars by the action of micro-organisms.

Reduction in colour of the ciders while in bottle was a regular feature, generally much more marked for low-acid ciders than for those with the higher acidities. The colour-figure indicates the numbers of c.c. of a .01 normal Iodine solution which had to be added to 10 c.c. of water to obtain a similar colour tone as that of the cider, when placed in a test tube side by side with the dilute Iodine solution and regarded from above.

The results taken as a whole indicate the difficulty of generalising as to the behaviour of cider in bottle when several weeks elapse between the date of filtration and bottling. The beverage obviously is relatively unstable and subject to abnormal changes which must be attributed to the action of bacteria or other micro-organisms, the extent of such changes being related to the character of the cider. The amount of the normal "secondary" alcoholic fermentation in bottle, for which yeast action is responsible, evidently will be difficult, if not impossible, to determine in the face of these other concurrent changes. While there is no doubt that it is related to both the character of the individual cider and the time of bottling, the results under consideration do not, by themselves

and for the reason given, permit of any definite conclusions as to the degree of relationship.

The results recorded in the following part of this paper throw very considerable light on the above on account of the indications given by them of the alteration in character of the cider in storage casks between the filtration and bottling dates.

B. THE INFLUENCE OF THE TIME OF BOTTLING.

General previous experience having indicated that for any given cider the time taken to develop natural condition in bottle, the amount of deposit, and the liability to and extent of development of "fliers" are very closely related to the time of the year at which it is bottled, the investigations under this head were directed towards the behaviour of certain selected ciders when bottled in each case at intervals of a fortnight or longer throughout the bottling period of the cider year. The individual ciders selected were chosen as representative of the respective types of common occurrence in which the natural rate of fermentation of the juice is more or less widely different.

The definite questions associated with time of bottling which it was attempted to settle in the experiments under this head were :

- (a) The effect of the nature of the storage vessel used for the cider prior to bottling.
- (b) The relation between the natural rate of primary fermentation of a cider and behaviour after bottling.
- (c) The influence of the amount of yeast food other than sugar present in the cider at the time of bottling.

Each of these points had been indicated in previous preparatory studies as having a direct bearing on the nature of the results following bottling at different periods of the year.

(a). *The Effect of Storage Conditions prior to Bottling.*

Experiments in 1922.

For this test a cider made from a juice with a medium rate of fermentation was selected. The fruit was milled and pressed on November 11th, 1921, the analysis of the juice showing specific gravity 1.066, malic acid .23 per cent., and tannin .14 per cent. It was filtered on January 12th, 1922, at a specific gravity of 1.025. The bottling experiment was started on February 8th, when the specific gravity was 1.021. The cider was divided into three parts. One part, I, was put in a hogshead cask, another part, II, was distributed in 7 small casks, and the third part, III, was stored in 8 large glass jars. In each case the container was completely filled and securely bunged to prevent access of air. At intervals of about a fortnight until mid-April, and thereafter at intervals of one month until August, a certain number of bottles were filled

from I, II, and III. In the case of I, immediately after each bottling the remaining bulk of the cider was transferred to a smaller cask, which was filled and then bunged down. In the case of II and III a fresh cask or glass jar of the original sets was used for each bottling. The bottles were kept at cellar temperature.

The bottled ciders were examined in December, 1922. The appended table (Table II.) shows the specific gravity at that time in the different samples.

The most marked result shown by this table is that while the specific gravity of the ciders bottled from the glass-jars, III, remained very nearly constant no matter what time they were bottled, there was a very appreciable drop in specific gravity in the samples bottled from the large casks, I, and a still more pronounced drop—which also set in earlier—in the case of the samples bottled from the small casks, II.

TABLE II.

		Specific Gravity, December, 1922;		
		I.	II.	III.
Date of bottling.		From large cask.	From small cask.	From glass jar.
February 8, 1922	..	1.018	—	—
" 22, "	..	1.017	1.013	1.017
March 8, "	..	1.016	1.011	1.017
" 24, "	..	1.016	1.011	1.017
April 14, "	..	1.016	1.010	1.017
May 15, "	..	1.013	1.004	1.017
June 12, "	..	1.009	1.001	1.016
July 20, "	..	1.007	1.001	1.015

The specific gravity records taken in this series were unfortunately not sufficient to demonstrate the complete story. As later work has shown, the specific gravity should have been taken in each instance at the time of bottling from the respective storage vessels, so as to show the gravity change in the storage vessel between the start of the experiment and the removal into bottle. It is now known that an important proportion of the gravity fall recorded in this experiment must have occurred before the individual samples were bottled. The results as stated must therefore not be regarded as indicative of the change in gravity after bottling. They represent the total change between the beginning and end of the experiment and include both the fall in the storage vessel and in bottle. It may, however, be stated that any drop in gravity in excess of three points may be taken as having occurred before bottling. The evidence from other series of experiments justifies this statement.

Notwithstanding this omission these results demonstrate the great importance of the kind of storage vessel used prior to bottling. In the glass jars, where the cider was kept without access of air, the cider retained its specific gravity well. In the large casks, where

the cider was exposed to the influence of the air through the pores of the wood, the lowering of specific gravity was considerable, and in the case of the small casks, where the surface is much greater in proportion to the volume of liquid, the gravity loss was extreme.

The importance of this point in practical cider-making cannot be over-emphasized. All who have had experience of cellar work are aware of the loss of liquid which occurs by evaporation through the walls of wooden casks. The place of the evaporated liquid is taken largely by air, which clearly is responsible for loss of gravity in the cider, as the above results show, and also for the development of acetification and other disorders produced by bacterial activity and encouraged by the presence of oxygen. Individual casks vary as regards the rate of evaporation, but all wooden vessels, unless specially treated, must be considered as open to serious objection in this connection for cider storage. It is clear that if cider is to be retained as nearly as possible in the condition in which it comes from the filter the sooner it is placed in an air-tight vessel the better. Attention is being given to the question of suitable vessels for the purpose. In this respect the French cider industry has already led the way by the introduction of glass-lined cement tanks, which some of the larger English firms are now also using.

The flavour and general character of the ciders in this series closely followed the specific gravity in the sense that deterioration in quality corresponded with fall in gravity. In fact the rate of gravity loss can very well be taken as indicative of the comparative progress of deterioration in all the series of trials dealt with in this section. The most marked changes in flavour were the hardening due to air effect in the case of the ciders stored in wood before bottling and the loss of aromatic and fruity quality in the same groups. These features were considered independently of changes in sweetness, the extent of which is sufficiently well recorded by the gravity figures, which register mainly the actual sugar loss.

There are two points in connection with flavour changes in bottle to which attention should be called. The first is noticeable only in the case of ciders with relatively high acidity and is remarkable for the development of a taste strongly resembling that of cooked apples. It is accordingly frequently termed the "apple pie" flavour. It was noted throughout the whole series of experiments that this flavour did not develop in every case in the sharper ciders. It occurred very frequently when these ciders had remained in cask for some time after filtration and before bottling. Corresponding samples bottled direct from the filter did not show it, nor did those stored in glass jars between filtration and bottling time. It should, therefore, be attributed to aeration influence, whether by the encouragement of the development of specific organisms or by chemical change only is not at present

known. The second point of flavour change to which attention is called is the development of a somewhat disagreeable musty flavour, associated with a corresponding aroma, which occurs more or less regularly when the cider has been in bottle for many months and a considerable amount of yeast deposit is present. It is believed that it is caused by decomposition of the dead yeast cells in the deposit, since samples kept free from standing deposit do not show a corresponding development of this flavour.

In respect of condition, *i.e.*, content of carbon dioxide, the earlier bottled samples invariably were more highly charged with carbonic acid than those bottled later. This may be taken as a general result in all the bottling investigations, the only cases where it does not apply being those in which cider sickness developed in occasional later bottlings. In such cases the result from the point of view of condition must be considered as abnormal, due to the intervention of the action of the sickness bacillus. At the same time the possibility of the development of the latter is a risk definitely associated with relatively late bottling, as previously pointed out in earlier Reports issued by Long Ashton.

Further in respect of condition in relation to time of bottling, it was obvious in all the series in these trials that the earlier bottled samples came quicker into condition as regards development of carbon dioxide. The later the bottling the slower became the development of condition until ultimately a point was reached where no appreciable amount of gas was formed, even after a prolonged period in bottle.

The influence of temperature on the cider after bottling was tested by placing some of the bottles from the early bottlings at three different temperatures in addition to the cellar-temperature (55°—58° F.), *viz.*, 32°—34° F., 68° F. and 77° F. When tested in December the samples kept at the low temperature showed the same specific gravity as when bottled (1.021), and the cider was completely unaltered and still. The samples kept at higher temperatures (68° F. and 77° F.) showed the same specific gravity (1.017) as the corresponding samples kept at cellar temperature and were practically in the same condition. It would appear, therefore, that except when the bottled cider is stored at a temperature so low that yeast activity is suspended, *i.e.*, near freezing point, or so high that the yeast is injured, it matters little as regards ultimate result on gravity loss what the storage temperature is.

Experiments in 1923.

The foregoing trials, carried out in 1922 were repeated on a more extensive scale in 1923. The details of the latter are included, not so much because of any fundamental new facts which they have revealed as on account of their value in confirming and amplifying the conclusions already stated in connection with the former.

There is one point shown by the data given to which attention may be called at this stage, viz., the marked fall in specific gravity shown by nearly all the ciders between the date of filtration and that of the first bottling a few weeks later. Its significance will be considered when the general conclusions to be drawn from these investigations as a whole are discussed at the end of this paper.

The 1923 trials were carried out with eight ciders made during 1922. On February 17th, 1923, a bottling was made from a 100-gallon cask of each cider, and at the same time 5 glass bottles of a capacity of half a gallon and 5 6-gallon casks were filled from each cask, and the rest of the cider transferred to a 60-gallon cask. Further bottlings were then made as follows :—

- (1) from the 60-gallon cask,
- (2) from one of the glass bottles and
- (3) from one of the small 6-gallon casks

on five successive dates, viz., March 1st, April 4th, May 2nd, June 1st and July 1st, 1923. After each bottling from the 60-gallon casks the casks were filled up with the same cider kept in bottles for the purpose and tightly bunged down.

The ciders used and the results in each case are set out in the following pages in Table III.

In this series of trials detailed chemical analyses were not made at the conclusion of the test, contrary to the usual practice for the experiments of the previous year. The latter had already shown that records showing specific gravity and acidity changes taken in conjunction with the usual sampling tests by taste and eye provided adequate data for the immediate purpose in view at this stage of the investigation. The consequent reduction in analytical work thus enabled a larger number of ciders to be included in the trials and a more general result on the immediate points at issue to be gained.

Taking the first cider, Kingston Black 1, an example of a dry cider, it will be seen from the table that the specific gravity of the samples bottled directly from the filter on November 27th, 1922 was 1.012 in December, 1923, whereas the samples bottled in February, 1923, only showed a specific gravity of 1.003. At the same time the first samples had a much better flavour and a smaller deposit in the bottles. The March and April samples did not show any appreciable difference in comparison with the samples bottled in February, but from May onwards the difference was marked, the samples bottled from casks being decidedly inferior to the earlier bottled ones. Those bottled in June and July again were inferior to the May samples. The small cask samples from June and July were very bad and highly acetic. The samples from the glass bottles had kept much better, the specific gravity remained the same, and the May, June and July bottlings were only slightly inferior in flavour to the earlier bottlings from the glass bottles.

TABLE III.

Cider.	Analyses of Juices and Ciders.				
	Specific Gravity.	Acidity, as malic acid. %	Tannin %	Alcohol %	Rate of fermentation at 25°C.
KINGSTON BLACK 1.					
Fresh expressed juice, Nov. 7, 1922	1.045	.46	.12	—	7.5
At filtration, Nov. 27, 1922	1.020	—	—	—	—
At start of bottling test, Feb. 17, 1923	1.005	.51	.12	4.4	—
CAP OF LIBERTY.					
Fresh expressed juice, Nov. 7, 1922 . .	1.044	.82	.17	—	8.0
At filtration, Nov. 27, 1922	1.022	—	—	—	—
At start of bottling test, Feb. 17, 1923	1.015	.79	.16	3.2	—
MIXED APPLES.					
Fresh expressed juice, Dec. 6, 1922 . .	1.012	.39	.22	—	6.3
At filtration, Jan. 25, 1923	1.016	—	—	—	—
At start of bottling test, Feb. 17, 1923	1.010	.41	.20	3.5	—
ROYAL WILDING.					
Fresh expressed juice, Dec. 4, 1922 . .	1.052	.24	.26	—	6.0
At filtration, Jan. 17, 1923	1.022	—	—	—	—
At start of bottling test, Feb. 17, 1923	1.017	.31	.25	3.8	—
CUMMY NORMAN.					
Fresh expressed juice, Dec. 21, 1922	1.056	.24	.37	—	3.1
At filtration, Jan. 31, 1923	1.023	—	—	—	—
At start of bottling test, Feb. 17, 1923	1.019	.37	.32	4.1	—
EGGLETON STYRE.					
Fresh expressed juice, Dec. 12, 1922	1.065	.36	.20	—	4.6
At filtration, Jan. 25, 1923	1.026	—	—	—	—
At start of bottling test, Feb. 17, 1923	1.020	.39	.16	4.8	—
KINGSTON BLACK 2.					
Fresh expressed juice, Nov. 28, 1922	1.059	.59	.18	—	3.0
At filtration, Jan. 18, 1923	1.025	—	—	—	—
At start of bottling test, Feb. 17, 1923	1.020	.53	.18	4.6	—
LAMBROOK PIPPIN.					
Fresh expressed juice, Dec. 15, 1922	1.042	.54	.20	—	4.0
At filtration, Jan. 9, 1923	1.027	—	—	—	—
At start of bottling test, Feb. 17, 1923	1.022	.56	.19	2.2	—

TABLE III—*continued.*

Cider.	Analysis of Ciders from bottled samples, December, 1923.			
	Specific Gravity.	Acidity % (as malic acid)	Deposit in bottle.	Flavour.
KINGSTON BLACK 1.				
Sample bottled from bulk direct from the filter, Nov. 27, 1922.				
Specific gravity 1.020	1.011	.30	Very small	Very good
Sample bottled from bulk 82 days after filtration, Feb. 17, 1923				
Specific gravity 1.005	1.003	.46	Small	Good
Sample bottled from large cask				
(a) Mar. 1, 1923	1.003	.49	Some	"
(b) Apr. 4, 1923	1.002	.46	"	"
(c) May 2, 1923	1.001	.48	"	Inferior
(d) June 1, 1923	1.001	.45	"	"
(e) July 1, 1923	1.001	.42	"	"
Sample bottled from small cask				
(a) Mar 1, 1923	1.004	.53	"	Good
(b) Apr. 4, 1923	1.003	.43	"	"
(c) May 2, 1923	1.002	.43	"	Inferior
(d) June 1, 1923	1.000	.79	Some and "fliers"	Bad, acetic
(e) July 1, 1923	1.001	1.02	"	Bad, very acetic
Sample bottled from glass jar				
(a) Mar. 1, 1923	1.003	.49	Some	Good
(b) Apr. 4, 1923	1.004	.44	"	"
(c) May 2, 1923	1.004	.46	"	Fairly good
(d) June 1, 1923	1.004	.45	"	"
(e) July 1, 1923	1.004	.46	"	"
CAP OF LIBERTY.				
Sample bottled from bulk direct from the filter, Nov. 27, 1922				
Specific gravity 1.022	1.020	.62	Small	Very good
Sample bottled from bulk 82 days after filtration, Feb. 17, 1923				
Specific gravity 1.015	1.011	.52	Some	Good
Sample bottled from large cask				
(a) Mar. 1, 1923—	1.010	.45	"	"
(b) Apr. 4, 1923	1.009	.44	"	"
(c) May 2, 1923	1.008	.44	"	"
(d) June 1, 1923	1.006	.44	"	Inferior
(e) July 1, 1923	1.006	.51	Small	"
Sample bottled from small cask				
(a) Mar; 1, 1923	1.009	.48	Some	Good
(b) Apr. 4, 1923	1.009	.56	"	"
(c) May 2, 1923	1.009	.72	Some and "fliers")	Inferior
(d) June 1, 1923	1.004	.86	"	Very inferior, acetic
(e) July 1, 1923	1.003	.78	"	Bad, acetic
Sample bottled from glass jar				
(a) Mar. 1, 1923	1.011	.49	Some	Good
(b) Apr. 4, 1923	1.010	.48	"	"
(c) May 2, 1923	1.010	.45	"	"
(d) June 1, 1923	1.010	.44	Small	Fairly good
(e) July 1, 1923	1.006	.50	"	Inferior.

TABLE III—*continued.*

Cider.	Analysis of Ciders from bottled samples, December, 1923.			
	Specific Gravity.	Acidity % (as malic acid)	Deposit in bottle.	Flavour.
MIXED APPLES.				
Sample bottled from bulk direct from the filter, Jan; 25, 1923				
Specific gravity 1.016	1.008	.37	Some	Good.
Sample bottled from bulk 23 days after filtration, Feb. 17, 1923				
Specific gravity 1.010	1.006	.36	"	"
Sample bottled from large cask				
(a) Mar. 1, 1923.. ..	1.006	.35	"	"
(b) Apr. 4, 1923	1.006	.35	"	"
(c) May 2, 1923	1.005	.36	"	Inferior
(d) June 1, 1923.. ..	1.004	.37	"	"
(e) July 1, 1923	1.003	.33	"	"
Sample bottled from small cask				
(a) Mar. 1, 1923.. ..	1.006	.32	"	Good
(b) Apr. 4, 1923.. ..	1.005	.38	"	Inferior
(c) May 2, 1923	1.004	.40	"	"
(d) June 1, 1923.. ..	1.002	.42	"	Very inferior
(e) July 1, 1923	1.002	.97	Some "fliers"	Bad, very acetic
Sample bottled from glass jar				
(a) Mar. 1, 1923.. ..	1.006	.34	Some	Good
(b) Apr. 4, 1923.. ..	1.006	.35	"	"
(c) May 2, 1923	1.006	.36	"	"
(d) June 1, 1923.. ..	1.006	.37	"	"
(e) July 1, 1923	1.006	.37	"	Fairly good
ROYAL WILDING.				
Sample bottled from bulk direct from the filter, Jan. 17, 1923				
Specific gravity 1.022	1.016	.34	Some	Good
Sample bottled from bulk 31 days after filtration, Feb. 17, 1923				
Specific gravity 1.017	1.015	.33	"	"
Sample bottled from large cask				
(a) Mar. 1, 1923.. ..	1.014	.33	"	Fairly good
(b) Apr. 4, 1923.. ..	1.014	.33	"	"
(c) May 2, 1923	1.012	.31	Small	"
(d) June 1, 1923.. ..	1.010	.30	"	Inferior
(e) July 1, 1923	1.009	.31	Very small	"
Sample bottled from small cask				
(a) Mar. 1, 1923.. ..	1.014	.37	Some	Fairly good
(b) Apr. 4, 1923.. ..	1.012	.36	"	"
(c) May 2, 1923	1.010	.36	Small	"
(d) June 1, 1923.. ..	1.008	.53	"	Very inferior
(e) July 1, 1923.. ..	1.008	.76	Some "fliers"	Bad, very acetic
Sample bottled from glass jar				
(a) Mar. 1, 1923.. ..	1.015	.33	Some	Fairly good
(b) Apr. 4, 1923.. ..	1.015	.33	"	Good
(c) May 2, 1923	1.015	.33	Small	"
(d) June 1, 1923	1.015	.34	"	"
(e) July 1, 1923.. ..	1.015	.35	"	"

TABLE III—*continued.*

Cider.	Analysis of Ciders from bottled samples, December 1923.			
	Specific Gravity.	Acidity % (as malic acid).	Deposit in bottle.	Flavour.
CUMMY NORMAN.				
Sample bottled from the bulk direct from the filter, Jan. 29, 1923				
Specific gravity 1.023	1.021	.30	Some	Very good
Sample bottled from bulk 19 days after filtration, Feb. 17, 1923				
Specific gravity 1.019	1.017	.31	"	Good
Sample bottled from large cask				
(a) Mar. 1, 1923	1.016	.31	"	"
(b) Apr. 4, 1923	1.017	.31	"	"
(c) May 2, 1923	1.017	.32	"	"
(d) June 1, 1923	1.015	.31	"	Fairly good
(e) July 1, 1923	1.015	.30	Small	Inferior
Sample bottled from small cask				
(a) Mar. 1, 1923	1.016	.31	Some	Good
(b) Apr. 4, 1923	1.016	.31	"	Inferior
(c) May 2, 1923	1.015	.31	"	"
(d) June 1, 1923	1.012	.65	"	Very infer. acetic
(e) July 1, 1923	1.011	.60	"	"
Sample bottled from glass jar				
(a) Mar. 1, 1923	1.018	.31	"	Good
(b) Apr. 4, 1923	1.018	.29	"	"
(c) May 2, 1923	1.018	.29	"	"
(d) June 1, 1923	1.017	.31	"	"
(e) July 1, 1923	1.015	.30	Small	Fairly good
EGGLETON STYRE.				
Sample bottled from bulk direct from the filter Jan. 25, 1923				
Specific gravity 1.026	1.024	.37	Small	Very good
Sample bottled from bulk 23 days after filtration, Feb. 17, 1923				
Specific gravity 1.020	1.018	.35	"	Good
Sample bottled from large cask				
(a) Mar. 1, 1923	1.018	.40	"	"
(b) Apr. 4, 1923	1.018	.35	"	"
(c) May 2, 1923	1.017	.37	"	Fairly good
(d) June 1, 1923	1.017	.37	"	"
(e) July 1, 1923	1.015	.40	"	"
Sample bottled from small cask				
(a) Mar. 1, 1923	1.017	.42	"	Good
(b) Apr. 4, 1923	1.017	.39	"	Inferior
(c) May 2, 1923	1.017	.44	"	Inferior, acetic
(d) June 1, 1923	1.012	1.01	"	Bad, very acetic
(e) July 1, 1923	1.013	.60	"	Very infer. acetic
Sample bottled from glass jar				
(a) Mar. 1, 1923	1.018	.36	"	Good
(b) Apr. 4, 1923	1.018	.40	"	"
(c) May 2, 1923	1.019	.36	"	Fairly good
(d) June 1, 1923	1.019	.37	"	"
(e) July 1, 1923	1.018	.45	"	"

TABLE III—*continued.*

Cider,	Analysis of Ciders from bottled samples, December, 1923.			
	Specific Gravity.	Acidity % (as malic acid).	Deposit in bottle.	Flavour.
KINGSTON BLACK 2.				
Sample bottled from bulk direct from the filter, Jan. 18, 1923				
Specific gravity 1.025	1.027	.53	Some	Very good
Sample bottled from bulk 30 days after filtration, Feb. 17, 1923				
Specific gravity 1.020	1.019	.39	"	Good
Sample bottled from large cask				
(a) Mar. 1, 1923	1.020	.30	"	"
(b) Apr. 4, 1923	1.020	.31	"	Fairly good
(c) May 2, 1923	1.019	.29	"	"
(d) June 1, 1923	1.018	.39	Small	Inferior
(e) July 1, 1923	1.017	.41	Small	Very inferior
Sample bottled from small cask			" fliers "	
(a) Mar. 1, 1923	1.020	.32	Some	Good
(b) Apr. 4, 1923	1.020	.33	"	Fairly good
(c) May 2, 1923	1.018	.30	"	Inferior
(d) June 1, 1923	1.014	.33	Small	Very inferr.
			Small	Bad, very acetic
(e) July 1, 1923	1.015	.70	" fliers "	
Sample bottled from glass jar				
(a) Mar. 1, 1923	1.020	.33	Some	Good
(b) Apr. 4, 1923	1.020	.32	"	"
(c) May 2, 1923	1.019	.29	"	"
(d) June 1, 1923	1.019	.28	Very small	"
(e) July 1, 1923	1.019	.30	"	"
LAMBROOK PIPPIN.				
Sample bottled from bulk direct from the filter, Jan. 9, 1923				
Specific gravity 1.027	1.020	.34	Some	Very good
Sample bottled from bulk 39 days after filtration, Feb. 17, 1923				
Specific gravity 1.022	1.018	.33	"	Good
Sample bottled from large cask				
(a) Mar. 1, 1923	1.018	.34	"	"
(b) Apr. 4, 1923	1.018	.33	"	Fairly good
(c) May 2, 1923	1.017	.34	Small	"
(d) June 1, 1923	1.014	.32	"	"
			Small	"
(e) July 1, 1923	1.012	.41	" fliers "	Inferior
Sample bottled from small cask				
(a) Mar. 1, 1923	1.018	.34	Some	Fairly good
(b) Apr. 4, 1923	1.016	.33	"	Inferior
(c) May 2, 1924	1.012	.34	Small	"
			Small	"
(d) June 1, 1923	1.012	.37	" fliers "	"
(e) July 1, 1923	1.006	.83	Small	Bad, very acetic
Sample bottled from glass jar			" fliers "	
(a) Mar. 1, 1923	1.018	.35	Some	Good
(b) Apr. 4, 1923	1.018	.34	"	"
(c) May 2, 1923	1.017	.34	Small	"
(d) June 1, 1923	1.016	.34	"	"
(e) July 1, 1923	1.017	.33	"	Fairly good

The next two ciders, made from Cap of Liberty and mixed apples respectively and also of the "dry" type, behaved in a similar manner.

The four remaining samples of cider, of the medium-sweet or sweet types in each case, did not vary very much in behaviour. The samples bottled before May kept well as a rule. Samples bottled during May, June and July showed a progressive deterioration when bottled from casks, especially when bottled from small casks, whereas the samples bottled from the large glass bottles did not show a marked difference between early and later bottlings.

(b). *The Influence of the Rate of Fermentation of the Juice.*

Three ciders, viz., A, the one used in the series of experiments described on pages 75-78, made from a juice with a medium rate of fermentation, B, made from a rapidly fermenting juice, and C, from a slow fermenting juice, were bottled at the following times: February 8th, March 8th and April 14th, 1922. In each case the samples were bottled from casks, which after the bottling were filled up with some of the same cider and bunged down.

The bottles were kept at cellar temperature and examined in December, 1922, when the specific gravities were as shown in the following Table (Table IV).

TABLE IV.

					Cider A.	Cider B.	Cider C.
Specific gravity	before	bottling	on				
February 8	..	..	..	..	1.021	1.021	1.036
Specific gravity	of	samples	bottled				
February 8	..	..	..	..	1.018	1.019	1.034
Specific gravity	of	samples	bottled				
March 8	..	..	..	..	1.016	1.016	1.033
Specific gravity	of	samples	bottled				
April 14	..	..	..	..	1.016	1.015	1.033

In these cases the drop in specific gravity was not excessive; it was least in the case of C, the sample with a slow rate of fermentation, where it was rather low. The amount of gas which was formed was just enough to make the cider nicely sparkling when poured from the bottle. The flavour of the cider in all three cases showed, however, a decided superiority for the samples bottled on February 8th in comparison with those bottled on March 8th, and the latter were in turn superior to the samples bottled on April 14th.

A temperature test was made in this series also. Samples of the bottled ciders were kept at 32°—34° F., 68° F. and 77° F. with the same result as in the preceding series, viz., that the ciders had kept quite unaltered at the low temperature and that the influence of the higher temperature upon the rate of fall in specific gravity was not considerable.

The results for gravity loss in this series were less striking than had been anticipated in view of previous experience. Discussion of their significance may be deferred until those with the two following series have been described, for the latter throw some light upon them.

In the next series, designed to show the effects of blending ciders of different rates of fermentation, the two ciders B (quick fermenting) and C (slow fermenting) were blended in equal parts and bottles were filled from cask on February 8th, March 8th and April 14th, as above.

When examined in December the specific gravities were as shown in the following Table (Table V).

TABLE V.

		Blend B. + C.	
Sample bottled	February 8	..	1.027
"	" March 8	..	1.027
"	" April 14	..	1.025

(c). *The Influence of Yeast Nutrients other than Sugars.*

In a further series, to ascertain the influence of the amount of yeast food present, to three sets of samples of the slow fermenting cider C was added phosphate of ammonia in varying quantities to increase the rate of fermentation by introducing this nitrogenous yeast food. These were bottled on February 8th at a gravity of 1.036. In December the gravities were as shown in the following Table (Table VI).

TABLE VI.

	Cider C.
Small dose of phosphate of ammonia (5 in 100,000) ..	.. 1.029
Medium dose of phosphate of ammonia (10 in 100,000) ..	.. 1.025
Large dose of phosphate of ammonia (20 in 100,000) ..	.. 1.020

These sets of gravity records shown by Tables V and VI taken in conjunction with those in Table IV are illuminating. In the first place, the result of blending B and C was a loss of gravity materially less than that occurring in B alone and even slightly less than in C alone, although in the latter instance no stress should be laid on the difference since it is no more than may occur at any time between one set and another of samples of the same cider. In the second place, the addition of nitrogenous yeast food to C resulted in a material increase in loss of gravity in all cases, the amount in each instance being in direct relation to the quantity of food added. The fermentation in bottle in the latter set was so strong that a large proportion of the bottles burst.

Taking the results in all the three series in sections (b) and (c) together, it seems clear that for this particular cider season the

residual amount of nitrogenous yeast food left in the individual ciders at the time of bottling was so small in all cases that yeast action in bottle was reduced to a point where pronounced differences in results were impossible. In other words yeast starvation was extreme throughout. The minor differences noted were just sufficient to indicate initial differences in the original juices in respect of natural rate of fermentation, but no more. A more decisive result could only have been obtained by starting the trials earlier than February, before yeast exhaustion had become so pronounced. This view is supported by the behaviour of individual ciders bottled as samples year after year in the course of the normal variety-trial work in the cider-house at the Institute. These samples are bottled direct from the filter at whatever period of the season the particular cider in question may reach the stage at which filtration is decided upon. Some are bottled early, others later. Some are of the rapid fermenting type, others of the slow fermenting group. While the gravity fall in bottle differs considerably in individual cases, the general experience is that an appreciably greater fall in gravity occurs when filtration and bottling are done relatively early in the life of a cider than when these operations are deferred until the cider is older. In making this statement a qualifying clause should be added with reference to the amount of fermentable sugar present at the time of filtration and bottling. While the actual amount does not appear to affect the results materially provided that an adequate quantity is present, it is obvious that when the quantity is very small the results may be abnormal because of exhaustion of sugar.

The question of the amount of assimilable nitrogen in the cider is clearly of first importance in deciding the subsequent behaviour of the cider in bottle. All records taken in connection with this work go to show, however, that there is little residual material of this kind left after filtration and hence in the average case the drop in gravity of cider in bottle after many months storage is rarely in excess of three points. The point is one of considerable significance as indicating the extent to which the crop of yeast produced during the primary fermentation of the expressed juice removes the greater part of the original nitrogen content. The result in an extreme case may be quoted. Some Bramley's Seedling apples were milled and pressed on December 12th, 1921, and filtered nine days later on December 21st, when the specific gravity was 1.038. Samples were bottled direct from the filter. The specific gravity of these samples at the time of writing, more than three years later, is 1.034, a drop of only four points having occurred during that period. The original rate of fermentation of the juice was over 14, an excessively high one. The original yeast crop thus in this case must have removed almost the whole of the

assimilable nitrogen with the result that, in spite of the very early bottling, very little more fermentation occurred in bottle than in the average case.

(d). *The Nature of the Deposit in Bottled Ciders.*

The behaviour of different ciders of similar age varies considerably as regards amount of deposit formed after bottling at any given date. While some idea as to extent of deposit can be deduced from knowledge of the following factors, (a) condition of ripeness of the fruit at the time of milling, (b) the chemical composition and rate of fermentation of the juice, and (c) the age of the cider at filtration and at bottling, a forecast of the result cannot at present be made with certainty.

The nature of the deposit is complex and it is for that reason that the behaviour of different ciders is so variable. The chief constituents are yeast cells, bacteria, remnants of the cellular tissue of the fruit, and insoluble substances, generally mainly pectin derivatives, settling out during storage in a bottle. The proportions of these differ according to the character of the fruit and the history of the cider. The following generalisations may be made.

The amount of yeast deposit is associated with and more or less in proportion to the quantity of available nitrogenous yeast food in the bottled cider.

The number of bacteria is relatively small in a perfectly sound cider, but is largely increased if any of the bacterial disorders develop after bottling. The relation of the latter to the deposit question has been considered in previous papers dealing with the individual disorders and the only case requiring special notice here is that of the acetic bacteria. These are mainly responsible for the formation of "fliers," especially in association with threads of filter pulp which are generally to be found in filtered ciders in very small amount. The development of acetic bacteria is contingent on the presence of oxygen in the bottle, either dissolved in the cider or in the air space between cork and liquid. There is a contest between the yeasts and bacteria for the available oxygen and the result is decided by the amount of oxygen present in relation to the relative capacity of the two groups of organisms. The chances of the yeasts, which are the dominant group when adequately nourished, are determined by the quantity of nitrogenous yeast food available. This, as previously shown, is decided by the interaction of several factors concerned with the fruit, and the history and age of the cider. The degree of risk of the development of "fliers" in a sample of bottled cider could probably be expressed by the ratio of available oxygen to nitrogenous yeast food.

The insoluble matter deposited from bottled cider during storage consists mainly of pectin derivatives which settle out in loose and

flocculent form. Most of this material is thrown out during the fermentation of the juice and in the early life of the cider. The age of the cider at the time of bottling is thus important in this connection. The other factor which can be definitely associated with the results is the acidity. Low-acid ciders, especially those with less than .4 per cent. malic acid, are much more commonly subject to this type of deposit than those of higher acidity.

CONCLUSIONS.

Reviewing the results in the experiments described, the following points appear definitely outstanding.

1. With the eleven ciders of widely different character in respect of chemical composition and initial rate of fermentation of the original juice, all bottled early in March, 1922, at specific gravities ranging from standards appropriate for dry to those for sweet ciders, the loss in gravity after ten months in bottle was in all cases trifling. The age of these ciders at the time of bottling varied from about three-and-a-half months to five months.

In all cases sufficient fermentation in bottle had occurred to bring the cider into adequate sparkling condition. Where the fall in gravity exceeded one point, the quantity of gas present was in excess of requirement.

Acidity changes in bottle, while in all cases showing a reduction, varied materially in individual ciders. The differences are attributed largely to the action of acid-destroying bacteria in varying degree, a complicating factor upsetting any close estimation of normal acidity change.

2. The behaviour of a cider from the time of filtration onwards varies to an extraordinary degree according to the conditions of storage to which it is subjected. The important factor determining storage changes appears to be aeration. Storage in wood results in material and long-continued loss of gravity, even when the casks are kept filled and tightly bunged. Storage in bottle or in larger gas-tight vessels prevents any marked gravity change in filtered ciders older than three or four months.

Transfer of a cider from large air-tight containers to bottles at any stage subsequent to three or four months after making can apparently be accomplished without serious alteration in result or much risk of stimulation of secondary bacterial disturbance. On the other hand, transfer from the wood to bottle as the cider ages is liable to be followed

by bacterial trouble, the risk and extent of which seems to increase during the summer following the making in proportion to the age of the cider at the time of bottling. The aeration factor must also be taken into account. Its action is probably complex, appearing to be in part due to stimulative effect on the partially starved yeast cells and in part to the encouragement to growth of bacteria which may lead to the production of suitable nitrogenous yeast food from constituents of the cider unassimilable by the yeasts in their original form. The evidence available suggests both modes of action, but further research on this part of the subject is needed before conclusions can be established.

3. The very slight gravity fall in filtered ciders three months old and upwards stored in air-tight containers is due primarily to deficiency of suitable nitrogenous yeast food.
4. The amount of deposit in bottle resulting from bottling in February and onwards can be approximately correlated with the age of the cider and the time of bottling for any individual cider. Bottling earlier than February direct from the filter gives deposit results of a variable nature: with some ciders the quantity of deposit has been less and with others more in the earlier bottling than in the February.

The work, to the point carried in this paper, has considerably clarified the position with regard to the problems of bottling cider under the system of natural conditioning. A fall in specific gravity of one or two points in bottle is sufficient to charge the liquor with an adequate amount of carbon dioxide to produce good sparkling condition. A larger fall results in too gaseous a state and too much deposit. The extent of gravity fall in bottle is determined by the age and character of the cider and is directly connected with the content of nitrogenous yeast food at the time of bottling. After active fermentation has been arrested and clearing accomplished by filtration or other corresponding means—the stage at which the greater part of the original nitrogenous yeast food has been removed by the primary yeast crop—the critical period in the life of the cider, when access of oxygen is definitely detrimental on account of accompanying bacterial activity, is reached. Cider destined for bottling should be bottled without delay then, if the residual nitrogen content is not too high: if so high that excessive fermentation in bottle will follow, storage in an air-proof vessel should be given until the excess fermentation is exhausted. There are no simple means yet available for direct nitrogen determinations, nor is it known at present what content of nitrogen should be aimed at. The next stage of the investigation will be largely concerned

with this aspect of the subject. It is obvious that the inherent difficulties indicated could be overcome by the adoption of a system of disgorging in connection with bottling practice, but such methods at present are rather beyond the range of the average maker. Hence, in this investigation attention has so far been directed to the elucidation of the principles affecting bottling, leaving the study of special methods to subsequent work.

CIDER MAKING TRIALS FOR THE SEASON 1923-24.

BY OTTO GROVE.

The 1923 crop of cider apples was a small one and the unsatisfactory weather during the ripening period, together with the wet state of the orchards during the harvest, which made it very difficult to collect and store the apples in sound condition, did not make for a good cider year. The ciders made were consequently on the whole not particularly good ; this was especially the case with the samples of the sharp varieties. In the bitter-sweet group the adverse season did not seem to have so much influence and several of the samples were very good. The average specific gravity of all the juices was fair, namely, 1.0518.

In the following tables will be found a list of ciders as exhibited for sampling on tasting day, the 15th July, 1924. It will be seen that the list includes some samples made from sharp varieties during the 1922 season for comparison, and the general opinion at the tasting was that they were in many cases superior to the 1923 samples of the same group.

Taking the individual samples, the first three were made from Lambrook Pippin apples received at Long Ashton on November 30th, 1923, and made up on January 7th, 1924. Upon arrival the apples were divided into three lots, No. 1 was stored in bins under cover, No 2 in bins in the open and No 3 in sacks under cover. In the bins the height of the apples was about 2 feet. As the result of the different methods of storage it was found that Nos. 1 and 2 were very similar both as regards the chemical composition of the juice, the rate of fermentation and the general character of the cider ; the two samples being very similar. No. 3 was, however, decidedly inferior ; the juice had a lower specific gravity (representing loss of sugar during storage), a lower acid and tannin content and a higher rate of fermentation. The storing of apples in sacks for more than a few days has a bad influence upon the apples and the resulting cider. It is always preferable to get them out in bins as soon as possible.

The Foxwhelp (1923) was only fairly good, the condition of the apples when received was not satisfactory. The Redstreak (1923) was fair, although not so good as earlier samples of this variety.

No.	Name of Variety.	District where Grown.	Date of Making.	Specific Gravity of Fresh Juice.	Malic Acid per cent.	Tannin per cent.	Rate of fermentation at 25°C.	Date of Filtering.	Specific Gravity, July, 1924.
SHARP VARIETIES.									
1	Lambrook Pippin (1923)	..	7/1/24	1.050	0.46	0.16	3.6	18/3/24	1.020 ₁
2	" " " "	Martock, Som.	7/1/24	1.050	0.47	0.16	3.8	18/3/24	1.022 ₂
3	" " " "	" "	7/1/24	1.048	0.43	0.14	4.5	27/2/24	1.019 ₃
4	" " " (1922)	" "	15/12/22	1.042	0.54	0.20	4.0	9/1/23	1.018
5	Foxwhelp (1923)	Nunnington, Her.	10/11/23	1.058	0.76	0.22	5.4	22/12/23	1.017
6	" " (1922)	Withington, Her.	26/10/22	1.054	0.66	0.28	6.6	4/12/22	1.018
7	" " " "	Yatton, Som.	21/11/22	1.050	0.93	0.28	3.2	28/12/22	1.019
8	" " " "	Credenhill, Her.	10/11/22	1.054	0.93	0.31	3.8	12/12/22	1.020
9	Red Streak (1923)	Breinton, Her.	1/11/23	1.054	0.58	0.19	5.0	22/11/23	1.022
10	Kingston Black (1923)	Nunnington, Her.	7/11/23	1.055	0.62	0.14	7.1	18/12/23	1.026
11	" " " "	Moorhampton, Her.	17/11/23	1.062	0.50	0.14	8.2	12/1/24	1.023
12	" " " "	Martock, Som.	7/11/23	1.063	0.61	0.16	6.0	6/1/24	1.029
13	" " " "	Michelney, Som.	12/11/23	1.060	0.48	0.18	7.0	5/1/24	1.029
14	" " " (1922)	Credenhill, Her.	20/11/22	1.054	0.63	0.19	2.7	20/1/23	1.019
15	" " " "	Kingweston, Som.	20/11/22	1.057	0.61	0.21	3.8	6/1/23	1.020
16	" " " "	Spetchley, Worcs.	19/11/22	1.057	0.59	0.22	3.1	22/1/23	1.021
17	" " " "	Withington, Her.	28/11/22	1.050	0.59	0.18	3.0	18/1/23	1.023
18	" " " "	Hele, Devon	20/11/22	1.035	0.52	0.19	2.5	3/2/23	1.024
19	" " " "	Congresbury, Som.	2/11/22	1.063	0.75	0.26	4.8	30/12/22	1.024
20	" " " "	Ledbury, Her.	20/11/22	1.055	0.63	0.20	3.1	3/2/23	1.020
21	" " " "	Hereford	20/12/22	1.061	0.59	0.19	2.6	26/2/23	1.019 ₄
22	" " " "	" "	20/12/22	1.061	0.59	0.19	2.6	12/3/23	1.022 ₅

APPLES—

No.	Name of Variety.	District where Grown.	Date of Making.	Specific Gravity of Fresh Juice.	Malic Acid per cent.	Tannin per cent.	Rate of fermentation at 25°C.	Date of Filtering.	Specific Gravity, July, 1924.
SHARP VARIETIES.—Cont.									
23	Cap of Liberty (1923)	Nunnington Her.	6/11/23	1.056	0.74	0.23	5.5	19/11/23	1.026
24	" "	Martock Som.	21/11/23	1.054	0.75	0.19	4.0	24/12/23	1.023
25	" "	" "	7/12/23	1.054	0.71	0.18	5.0	19/1/24	1.029
26	" "	Muchelney, Som.	12/11/23	1.050	0.76	0.20	4.0	1/1/24	1.029
27	" " (1922)	Martock, Som.	23/11/22	1.051	0.95	0.21	3.0	15/12/23	1.032
28	Spice Apple (1922)	North Cadbury, Som.	15/12/23	1.042	0.63	0.17	3.0	2/1/23	1.022
29	Crimson King (1922)	Chard, Som.	21/11/22	1.044	0.64	0.17	4.1	21/11/22	1.022
30	Tom Putt (1922)	Ledbury, Her.	16/11/22	1.048	0.68	0.15	6.0	6/12/22	1.027
31	Goose Apple (1922)	Hereford "	11/11/22	1.045	0.60	0.17	3.3	15/12/22	1.028
BITTERSWEET VARIETIES—									
32	Strawberry Norman (1923)	Hereford "	15/11/23	1.057	0.34	0.35	9.7	18/12/23	0.016
33	" "	Breinton, Her.	1/11/23	1.058	0.37	0.32	8.0	23/11/23	1.019
34	Argile' Grise "	Byford, Her.	15/11/23	1.048	0.18	0.18	6.8	17/12/23	1.019
35	Bramtot "	" "	15/11/23	1.052	0.20	0.27	6.4	2/1/24	1.018
36	White Jersey "	Moorhampton, Her.	2/11/23	1.058	0.35	0.25	9.6	12/11/23	0.017
37	White Norman "	Nunnington, Her.	5/11/23	1.052	0.42	0.20	9.2	26/11/23	1.020
38	Cummy Norman "	Hereford "	9/11/23	1.060	0.27	0.19	12.0	4/12/23	1.021
39	Frequin Audievre "	Byford, Her.	15/11/23	1.053	0.17	0.28	7.4	17/12/23	1.022
40	Royal Jersey "	Martock "	12/11/23	1.056	0.17	0.25	4.0	18/12/24	1.026
MIXED APPLES—									
41	Mixed Apples	Nunnington, Her.	6/11/23	1.054	0.64	0.17	8.0	4/12/24	1.0186
42	" "	" "	6/11/23	1.054	0.64	0.17	8.0		1.0117
43	" "	" "	6/11/23	1.054	0.64	0.17	8.0		1.0138

MIXED APPLES.—*Cont.*

44	"	"	"	"	"	"	7/12/23	1.055	0.39	0.20	6.0	14/1/24	1.016 ₉
45	"	"	"	"	"	"	7/12/23	1.055	0.39	0.20	6.0		1.006 ₁₀
46	"	"	"	"	"	"	7/12/23	1.055	0.39	0.20	6.0		1.002 ₁₁
47	"	"	"	"	"	"	7/12/23	1.055	0.39	0.20	6.0		1.021 ₁₂
48	Mixed Apples	"	"	"	"	"	7/12/23	1.055	0.39	0.20	6.0		1.020 ₁₃
49	"	"	"	"	"	"	7/12/23	1.055	0.39	0.20	6.0		1.021 ₁₄

CULINARY VARIETIES—

50	Branley's Seedlings (1922)	Hereford	"	"	26/2/23	1.038	0.66	0.08	9.0	12/3/23	1.011
51	Lane's Prince Albert (1922)	Ross, Her.	"	"	8/12/22	1.042	0.69	0.10	8.3	19/12/22	1.020
52	Warner's King (1922)	Churchill, Som.	"	"	12/10/22	1.042	0.98	0.09	9.5	19/10/22	1.027

1.	Fruit stored in bins under cover.	8.	Juice racked four times.
2.	" " " in the open.	9.	" " filtered.
3.	" " in sacks under cover.	10.	" " racked twice in tubs.
4.	Juice pasteurised and fermented with pure yeast No. 4.	11.	" " racked twice.
5.	" " " " " " No. 6.	12.	" " pasteurised and fermented with yeast 22.
6.	Juice filtered.	13.	" " " " " " 8.
7.	" " " " " " " " 80.	14.	" " " " " " " "

In the case of all the Kingston Black ciders the condition of the apples when received was not good ; they were all past the best stage for cider making. Nos. 12 and 13 were the best, but the 1922 samples were generally considered superior. The same was the case with the Cap of Libertys ; here also the 1923 samples were made from over ripe apples.

The bitter-sweet group contained some of the best samples of the season. They were upon the whole of good quality, especially the three French varieties, Argile Grise, Bramtôt and Frequin Audièvre, which were very nice ciders with a fine soft flavour and fruity aroma.

Ciders were made from many different lots of mixed apples, of which two were exhibited on the tasting day for comparison as to the effect of filtering and racking.

The juices in Nos. 47, 48 and 49 had all been pasteurised by heating to 158° Fah. in an open steam pan. This is evidently an unsatisfactory way since the exposure to the air during the heating is very liable to give the juice a cooked flavour. In pasteurisation experiments in progress at present the juices have been pasteurised, directly after pressing, by passing them through a pasteurising apparatus of French manufacture, which is constructed in such a way that the juice during the pasteurisation process passes through a set of tubes and does not get exposed to the air before it is completely cooled in the apparatus. This apparatus is giving very promising results and the difference in flavour between juices before and after pasteurisation is negligible.

SULPHUR DIOXIDE AS A PRESERVATIVE FOR FRUIT.

BY B. T. P. BARKER AND O. GROVE.

Sulphur dioxide (SO_2), the gas formed when sulphur burns in the air, possesses antiseptic properties which have been known and used for practical purposes almost from time immemorial. It has been utilised extensively for hundreds of years in the wine industry, especially for white wines, and nearly all the French white wines are treated with it at the present day. This is partly done to check fermentation and partly to prevent the development of micro-organisms causing disorder in the wines. For this purpose the dosage is generally applied in the form of gas produced by burning sulphur in the casks, or in solid form combined with a base, such as potassium meta-bisulphite and bisulphite of lime. Lately it has also been used in the liquid form, the gas being condensed under pressure into a liquid. This form is preferable, since it permits of using exact weighed amounts.

Its use as a preservative is frequent also in the case of other fermented or fermentable beverages, such as beer, cider and various non-alcoholic sweetened liquors. Custom has sanctioned the practice as legitimate and experience has proved that its effects on the human system are not harmful provided that the dosage is not permitted to exceed certain limits of free sulphur dioxide.

Various articles of food can be preserved from decomposition by it. It has been found of particular service in the case of fruit and its use for fruit preservation forms the subject of this paper.

Its special value in this connection is its volatility. If, for example, fruit is preserved by immersion in a dilute aqueous solution of the gas, it can be freed from the preservative when required for consumption by the simple expedient of boiling, the gas being rapidly driven off at the temperature of boiling water.

In modern times it has played an important part in the jam-making industry as a preservative for fruit pulp. The latter article, while unsuited for the production of the highest class of preserves, is nevertheless a commodity of a distinctly useful order in particular cases for the manufacture of a cheap, wholesome jam, provided that it has been well preserved. It enables the

manufacturer to handle a much larger quantity of fruit in glut seasons than he could otherwise do, since, by converting into pulp the part of the crop which it is impossible for him to make up into jam during the fresh fruit season, he can put it aside in store until pressure of work in the factory has slackened.

During the course of the war the present writers were closely concerned with the manufacture of a considerable quantity of fruit pulp and their experience with the product, while illustrating its value from the different points of view of the fruit grower and the jam boiler, demonstrated also inherent difficulties in its preservation in satisfactory form. When large quantities are made, storage in wooden casks is adopted. Since these are not absolutely air-tight and sulphur dioxide is both volatile and readily oxidisable, the dose of preservative added as adequate in the first instance becomes in course of time reduced below the toxic limit for the reasons just stated. If, when that time is reached, it is necessary to carry the fruit over a further period of storage, a supplementary dose of the preservative must be added. Otherwise, as not infrequently has occurred, moulds, yeasts, and bacteria begin to invade the pulp and it becomes worthless. Thus, by the time some pulps are used, the total quantity of preservative added may be relatively considerable and, although little may remain in the pulp as such, there is an appreciable amount of free or combined sulphuric acid left, resulting from the oxidation of the non-volatilised part of the sulphur dioxide.

For these reasons the writers turned their attention to the general question of the preservation of fruit by sulphur dioxide with the object of discovering, if possible, an alternative method to pulping which should not be open to the objection of the use of a relatively large quantity of preservative. The method of preservation herein described is the outcome.

The objects of the experiments were to ascertain (a) the smallest possible dose of sulphur dioxide which must be added to fruit in the first instance to inhibit the development of moulds, yeasts and bacteria, (b) the conditions under which such preserved fruit should be stored to render, if possible, further addition to the preservative unnecessary, (c) the effect of the preservative on the fruit itself and (d) the possible uses other than jam-making to which fruit so preserved could be put.

A. Dosage of Sulphur Dioxide required for Preservative Effect.

The earlier series of experiments were concerned primarily with this point. For obtaining accurate results it was clear that precautions were necessary in respect of possible diminution in the amount of sulphur dioxide actually available for preservative purposes by (a) evaporation, (b) oxidation, and (c) combination

with constituents of the fruit. The experiments were therefore made under the following conditions.

The fruit selected for trial, in all cases used as soon as possible after being picked and in perfectly sound condition, was packed in glass jars fitted with lids for hermetical sealing, such as are commonly utilised for fruit bottling. The preservative solutions to be tested were then simply poured over the fruit, the latter being completely immersed and the jar filled with the solution so as to leave the least possible air space. The lid was then affixed securely to prevent access of air or escape of sulphur dioxide.

Strengths of the sulphur dioxide solution ranging from 0.02 per cent. to 2 per cent. were tried. In preparation of the solutions sulphur dioxide gas was led into cold water until the water contained 4-5 per cent. of the gas in solution. The exact strength was then determined by titration with a 0.1 normal solution of Iodine, and the stock solution diluted to the required degrees.

Experiments were carried out with the following fruits: apples, plums, raspberries, loganberries, black and red currants, blackberries, gooseberries, strawberries and oranges. With the exception of gooseberries and black and red currants completely satisfactory results were obtained with all solutions of appropriate strength. With plums especially, of which all the well best known commercial varieties were tried, the results were excellent. In the case of black and red currants and gooseberries the fruits kept very well, but a certain hardening of the skins took place, which did not completely disappear when the fruit was stewed or converted into jam.

As regards strength of solution necessary to give satisfactory preservation, all strengths below .06 per cent. SO_2 were inadequate. Occasional instances occurred in which solutions below that limit showed complete absence of development of any micro-organisms, but the results were not sufficiently consistent. Strengths ranging from .06 to .08 per cent. have proved almost invariably satisfactory and from .08 per cent. upwards complete preservation has been invariably obtained in all the series of tests at Long Ashton. At the Campden Research Station, where the method has since been tried on a semi-commercial scale, occasional failures with .08 per cent. solutions have been experienced in the case of raspberries. It is believed that these were attributable to no inadequacy in the preservative power of the solution at that strength, but to packing of the fruit in the containers. The latter were large earthenware jars of 8 gallons capacity. Such a mass of soft fruit of the raspberry character tends to become compressed into a dense mass, to the interior of which it is not easy for the preservative solution to penetrate. Failure in such cases is not surprising unless, before the jars are sealed, particular care is taken to ensure proper mixing of fruit and solution. Another possible contributory cause may

have been disproportion between the amount of fruit and the volume of preservative solution. On this point the following results of the Long Ashton trials have some bearing.

Analyses have shown that after storage of fruit in the preservative solution for some time in sealed air-tight jars the strength of sulphur dioxide in the solution is greatly reduced. This result is well illustrated by the accompanying analysis made of the contents of a jar of Monarch plums preserved in a 0.08 per cent. solution of sulphur dioxide and examined after 8 months.

TABLE I.

			Weight in grammes.	Sulphur dioxide per cent.
Plums	..	..	210.9	0.015
Liquid	..	..	267.1	0.014
Whole Sample	..	..	478.0	0.014

(About 1/5th of original strength).

Allowing for the quantity of sulphur dioxide absorbed by the plums represented in this table as uncombined SO_2 , there is an actual loss of more than half the original amount added. This loss may be due either to oxidation to sulphuric acid or sulphates or to combination with constituents of the fruit. The available evidence deduced from other analyses suggests the latter as the main source of loss. Hence the proportion of fruit to preservative solution in the container may be of importance in special cases, since an unduly large amount of the former may lead to a reduction of sulphur dioxide strength below the preservative limit, with disastrous results on keeping quality. In practice this probably rarely occurs since, unless the fruit is very closely packed, the volume of solution required to cover it is sufficiently large to ensure the presence of a safe amount of sulphur dioxide.

Examination of the strength of the solution at various periods during storage has shown that the reduction in sulphur dioxide content is of a dual character. Within a few days after bottling there is a large loss, generally equal to about one-half the original amount added: after that time the rate of loss slows down rapidly and further reduction occurs very gradually. Presumably the initial rapid decline in strength of the solution is due very largely to diffusion into the fruit, of which in most cases there is about the same weight in bottle as that of the solution. The slower change later is probably representative of actual chemical changes.

In view of these results it would appear that, while it is necessary to use the preservative solution of a strength not less than 0.08 per cent. SO_2 to allow for absorption by the fruit, one of a concentration of 0.04 per cent. or thereabouts is actually sufficiently toxic to inhibit the growth of micro-organisms which may be placed in it. This figure is thus of significance in connection with the

preservation of wines, cider and other beverages. It should not, however, be taken as infallible, since investigations at Long Ashton on this subject in connection with cider have shown that the toxic limit varies according to the conditions of nitrogenous nutrition of the organisms. It is interesting to find that this figure, arrived at directly from the fruit bottling experiments, is practically identical with the content of sulphur dioxide (free and combined) permitted by the French Government in wines.

B. Conditions of Storage of Material preserved with Sulphur Dioxide Solutions.

The foregoing work was, as already stated, carried out entirely in vessels from which air was absolutely excluded. Since fruit pulp is usually stored in bulk in wooden casks, which, as the cider work at Long Ashton has repeatedly proved, are far from air-tight, and since sulphur dioxide is both readily volatile and oxidizable, the results described may only be applicable for a relatively short time for pulp or fruit stored in this way in bulk. Recent trials at the Campden Research Station have shown that whole fruit stored in the wood in a 0.08 per cent. solution of sulphur dioxide keeps sound for an unexpectedly long time when the casks are securely bunged. On the other hand pulp behaves very irregularly.

The importance of using air-tight vessels was demonstrated in a few isolated instances in the preceding series of experiments, where the rubber rings used to make the air-tight seal for the glass jars became defective during the prolonged storage. In those cases moulds began to develop in the jars even when the strength of the solution used was in the first instance well above the toxic limit.

Since the use of casks is so convenient for storage purposes, various methods of overcoming the difficulty of air access have been tried, none so far with complete success for pulp. Following out a suggestion that the presence of small amounts of a suitable chemical acting as an inhibitor for oxidation might slow down oxidation sufficiently to retain the sulphur dioxide in toxic amount, a number of substances unobjectionable from the food point of view were tested in this respect. These included glycerine, salt, various sugars, gum, lactic and tartaric acids, and alcohol. The appended Table II. gives some of the results and in certain instances shows some evidence of inhibitory action. Nothing so far tried has been marked enough in its action to offer promise of practical significance, but the possibility of further advance along this line should be kept in mind.

The results in Table II. for the control untreated solutions show the rapid loss of sulphur dioxide when air has free access to the liquid. It is clear, therefore, that the exclusion of air must be an essential point in any storage system utilised when this antiseptic is adopted as the preservative agent.

TABLE II.
RATE OF LOSS OF SO₂ IN AQUEOUS SOLUTIONS IN PRESENCE OF SMALL
AMOUNTS OF OTHER SUBSTANCES.

Series 1.—

Treatment.	Substance added.	% Content of SO ₂ at end of test.
50c.c. of 1 per cent. solution, with addition of substances named. Kept in open bottles for 25 days at laboratory temperature.	Nil. control a.	0.0
	Nil. control b.	0.0
	Glycerine 1 drop	0.0128
	" 2 drops.	0.0320
	" 10 "	0.0064
	" 20 "	0.0128
	Salt 0.2%	0.0128
	" 0.4%	0.0128
	Dextrose 0.4%	0.0256
	" 1.0%	0.0256
	Gelatine 0.1%	0.0128

Series 2, 3, 4, 5 and 6.—

Treatment.	Substance added.	Iodine Value*	
		at start	at finish
Series 2.—			
100c.c. of SO ₂ solution (about 2.3% strength), kept in large closed bottle for 5 days and agitated in shaking apparatus daily for 1 hour.	Nil.	7.3	5.4
	Cane sugar 1%	7.4	5.6
	„ 2%	8.5	6.7
	„ 5%	7.2	5.2
	„ 10%	11.4	8.1
	„ 20%	8.6	5.9
	„ 50%	6.8	4.0
	„ 60%	7.0	3.0
Series 3.—			
As in Series 2, except that strength of SO ₂ solution used was approximately 1% and duration of test 3 days.	Nil.	3.9	3.6
	Alcohol 3%	3.4	3.4
	Lactic Acid 1%	3.8	3.5
	Tartaric Acid 1%	3.8	3.6
	Gum 0.2%	3.3	3.1
	Dextrose 5%	3.7	3.4
Series 4.—			
As in Series 2, but duration of test 10 days,	Nil. a.	8.6	3.4
			(Stopper leaking)
	„ b.	8.6	5.8
	Alcohol 1%	8.4	5.1
	„ 2%	8.3	5.7
	„ 4%	8.4	5.7
	„ 6%	8.1	5.4
Series 5.—			
As in Series 2, but duration of test 4 days.	Nil.	8.2	3.5
	Alcohol 1%	8.0	3.9
	„ 2%	8.0	4.3
	„ 3%	7.7	4.2
	„ 4%	7.7	4.3
Series 6.—			
As in Series 2, with stronger SO ₂ solution.	Nil.	11.8	7.0
	Alcohol 3% +		
	Cane Sugar 3%	11.2	7.3
	Alcohol 3% +		
	Glycerine 1%	11.5	7.7
	Cane Sugar 2% +		
	Glycerine 1%	11.4	7.4

* Expressed in number of c.c. of .1 N Iodine Solution used in titration of 1c.c. SO₂ solution.

The substitution of another form of container for bulk storage in the place of wood has been considered. The objection in all cases so far examined which yield satisfactory storage is the relatively high cost of the storage vessel. As opportunity arises other forms will be examined. The problem of the container is in fact practically the same as that which the writers have under investigation in connection with cider and to which they have already referred in their article on "The Bottling of Ciders" which appears in another part of this Report.

But for its cost, the ideal container for work on a large scale would probably be the glass-lined cement tank used so extensively in France for the storage of wine and cider. Casks well coated inside with paraffin wax or one of the special cask linings would serve the purpose, as long as they could be kept airtight.

Some experiments with small cement containers (cement 1 part, sand 2 parts, Pudlo 5%) covered with several layers of paraffin wax and mixtures of paraffin wax and rosin have been made. With them there has invariably been a certain blackening of the fruit and the wax cover protecting the surface of the cement has been attacked in places.

C. The Action of Sulphur Dioxide on Fruit.

Apart from the preservative action of sulphur dioxide by inhibiting the growth of micro-organisms, this substance has a definite effect on the fruit itself.

Its action at strength 0.08 per cent. solution on certain enzymes naturally present in the fruit was investigated some time ago by Miss Watson and Mrs. S. P. Wiltshire in the laboratory at Long Ashton. They found that the enzymatic activities of diastase, invertase and zymase were completely stopped in a solution of that strength. It was concluded that the same would be the case when the fruit itself was kept in a similar solution. Subsequent experience in practice has provided this conclusion to be justified. Probably all enzyme activity within the fruit is stopped and the enzymes themselves destroyed, the living cells of the fruit being killed at the same time. Appleyard, continuing work on this part of the subject at the Campden Research Station, has recently obtained direct evidence on this point, detailed particulars of which will be published later.

It has been found that fruit preserved in this way shows a progressive loss of "setting" or "gelling" power when made into jam according to length of time it has been stored in the solution. The suggestion has been made that this reduction of "gel" value is due to reduction of pectin content by its conversion to pectic acid or other derivatives by the action of the enzyme pectase. On that assumption this enzyme would need to be resistant to sulphur

dioxide. The evidence available is against this view. Apart from the improbability of a particular enzyme remaining unaffected when all others are destroyed, there is no occasion to assume that the pectin change in this case is brought about by the enzyme. Pectin solutions depreciate regularly in "gel" value on long standing and fruit pulp, in which all the enzymes are destroyed by boiling, shows a similar deterioration. It is difficult to obtain satisfactory comparative figures, but there has been no clear evidence during the course of this work to show that pectin loss is much more rapid in the one case than in the other. The writers' view is that in each instance the pectin change is a gradual hydrolysis taking place in an acid medium without the intervention of pectase and that the rate of change is determined by the composition of the system.

A noticeable change produced in the fruit by the preservative solution is a marked bleaching of the colour. The red colouring matters are those most affected. Red plums, strawberries, red currants and, to a rather less extent, raspberries and loganberries lose their red colour, being either completely bleached to white or retaining in various degrees a pink tint. The blue and purple colours are more resistant. Thus black currants, blackberries, damsons and blue plums remain of a more natural appearance. Yellow and green pigments are little affected by the 0.08 per cent. solution. Greengages and yellow plums are accordingly not noticeably changed. The loss of colour, where it occurs, is temporary and persists only so long as sulphur dioxide is present. When the fruit is removed from the preservative solution and subjected to heat in jam-making or cooking, the sulphur dioxide is driven off and the original natural colour returns. A slight proportion is apparently permanently destroyed, since the final colour obtained after heating is rather less deep than the original: but so insignificant is the loss that the method has no drawbacks in its application on that account.

The remaining action of the preservative solution calling for mention is the toughening effect on the skins of gooseberries and currants to which reference has been made earlier in the paper. This is a definite disadvantage in the use of the method for these fruits and so far no means of overcoming it have been found.

D. Applications of the Method.

The previous part of this paper has been concerned with the detailed description of a method by which fruit can be preserved whole for an indefinite time in a solution of sulphur dioxide of the lowest possible effective strength. So weak is it in fact that after treatment and without removal of the antiseptic, the quantity of the latter present in the fruit itself is no greater than is permissive

by French law in wines and ciders. When in addition there is taken into account the point that in heating the preserved material the sulphur dioxide is practically entirely driven off, it is evident that there is here a simple method of fruit preservation suitable for any purpose for which the fruit can be used after cooking and free from any objection on the score of effect on the health of the consumer.

The original purpose in view at the start of the investigation was to arrive at a method of dealing with fruit pulp which would render the use of the latter in jam manufacture less open to objection than at present. In this matter the interest of the fruit grower is considerable, for fruit pulping enables the jam industry to absorb more fruit in seasons of heavy crops and gluts than could be taken if the fruit could only be converted into jam while in the fresh condition. From a more general point of view also a method which enables supplies of fruit to be put aside until required, in that way relieving congestion in the jam factory during the height of the fresh fruit season, must tend to the production of jam under better conditions and from sounder raw materials.

The main result of the work has been not so much to improve the position in respect of the fruit pulping method—although to a material extent this has been done by the information gained both on the conditions of storage required and the reduced quantity of preservative which can be made effective—as to provide an alternative method of preserving the fruit which possesses great advantages over the pulping method. The most important of these are (a) great saving in time, the fresh fruit being packed direct into the storage vessel and then simply covered with the preservative solution and sealed down; (b) larger quantities of fruit can be preserved during the fruit season; (c) no preliminary cooking or pulping, thus rendering unnecessary the provision of special pulping apparatus and equipment; (d) the fruit is preserved whole instead of being reduced to a state of pulp, enabling a more attractive grade of jam to be made; (e) less sulphur dioxide is required for preservation; (f) the costs of preservation are reduced very greatly by the elimination of the boiling and pulping process; (g) the preserved material keeps better; and (h) the quality of the jam made from the preserved material is much superior, being almost on a par with that of jam made from fresh fruit. Relating to the latter point the following analysis of jam (Table III. p. 106) made from fruit preserved in this manner is of interest in showing that the preservative is practically eliminated in the course of stewing and jam making. These figures were furnished by the sample of Monarch plums, other details concerning which have already been given in Table I.

TABLE III.

	Weight in grammes.	Sulphur dioxide per cent.
<i>Composition after stewing</i>		
Plums	102.8	0.007
Liquid	54.5	0.004
Whole Sample ..	157.5	0.006
<i>Composition of Jam</i> ..	—	0.003

The method is therefore put forward not as a substitute for pulping in the jam industry but as one to supercede it by virtue of its superiority in almost every respect. It is in addition equally applicable to jam making on a smaller scale and under domestic conditions. While normally in the latter case the stock of jam is made during the course of the fruit season from fresh fruit, there are occasions, particularly where persons use their own home-grown fruit, when it is a distinct advantage to be able to put aside a supply of fruit to await conversion into jam until a convenient opportunity.

Fruit thus preserved also serves a valuable purpose outside jam making. It can be brought into use in all respects in place of canned or bottled fruit. For the past four years the writers have tested it under domestic conditions as stewed fruit and for pies and puddings, and have found it as good as fruit bottled and sterilised in the ordinary way. If anything, the flavour is rather better. For red fruits the colour is sometimes slightly less. It is necessary to observe a little precaution when used in the home. It is, of course, unfit for consumption until it has been cooked, but, since all the uses proposed involve cooking in any case, this does not incur any additional operation. Generally by the time the fruit is cooked the sulphur dioxide has been completely carried off in the steam. Before finishing off the stewing it is, however, advisable for those unacquainted with the method to taste the fruit to ascertain if any flavour of the preservative remains. Its flavour is so pronounced and familiar to all that very small amounts can be readily detected in this way. If any taste is noticeable, the cooking should be continued for a slightly longer time till nothing can be detected. It is then in fit condition for consumption. When used in tarts and puddings this procedure is not possible. As a precautionary measure in these cases the fruit may be stewed for a short time and kept at the boil for a few moments before being placed in the tart or pudding, the latter being cooked in the usual manner. This pre-cooking is not generally necessary, but is a simple means of ensuring satisfactory results.

For home use this method of preserving is proposed as a substitute for bottling on account of its simplicity and the saving of time and trouble. The bottling method is equally good as regards quality of product and is absolutely safe in the sense that there is no risk of preservative being taken into the system of the consumer :

in other respects the advantage rests with the sulphur dioxide method.

There are other possibilities with regard to details of method of treatment, handling of the produce and mode of use which offer promise of increasing the utility of this form of preservation. Investigations on these are now in progress at the Campden Research Station.

E. Details of Method for General Use.

While the details of the method have been indicated earlier in the paper in connection with the experimental work, the particulars advised for general use may be somewhat amplified.

Fresh gathered fruit in sound condition should be selected for preservation. The preservative fluid should be an aqueous solution of sulphur dioxide of a strength not less than 0.08 per cent. nor more than 0.1 per cent. SO_2 . The fruit should be prepared as for bottling, stalks, etc., being removed. It should then be placed in the storage vessel, the latter being well filled with the fruit and care being exercised that packing in a solid mass does not occur. In the case of soft, easily compressible fruit, such as raspberries, which readily aggregate into a solid mass, a small quantity of the solution should be placed first in the receptacle and the latter agitated at intervals during the packing, further liquid being added as the vessel is filled up. This will ensure thorough mixing of the fruit and preservative. When sufficient fruit has been added, the vessel should be filled as completely as possible with the solution, to cover the fruit entirely and leave the smallest possible air-space above. The vessel should then be sealed down. It is important to see that the seal is airtight. Provided these operations are properly carried out, no further attention should be required until the fruit is wanted for use. The vessel is then unsealed and the fruit removed. The liquor in the vessel may be used with the fruit at discretion. It contains appreciable quantities of flavouring substances diffused from the fruit. Its use, however, should be accompanied by rather longer cooking than when the fruit is used without it, for there is more of the preservative to be driven off. When the fruit is to be used without it, the liquor should be drained off and the fruit itself may be rinsed with water to remove any adherent liquor.

As regards the type of storage vessel, for small scale work fruit bottles and earthenware jars are satisfactory. As to the methods of sealing these and suitable receptacles for larger scale work detailed information can be obtained on application from the Resident Director, Research Station for Fruit and Vegetable Preservation, Chipping Campden, Glos. Supplies of the preservative solution of standard strength can also be procured from that institution.

In conclusion, it may be stated that the recent Departmental Committee on Preservatives appointed by the Ministry of Health have had this method of preserving fruit under consideration, and in their recently issued Report have recommended that sulphur dioxide within limits which somewhat exceed those required in this connection should be permissible for fruit preservation. It may, therefore be accepted that the use of this preservative in the manner here indicated is regarded as legitimate and not detrimental to health. The publication of the details of this work has been deferred for some time so that the recommendations of that Committee might be available for reference.

MANURIAL REQUIREMENTS OF THE BASKET-WILLOW.

BY H. P. HUTCHINSON.

Under the commercial system of cultivation of basket-willows it is seldom that manures are applied. The crop is generally grown on wet alluvial tracts, the soil of which is considered to be "rich," being able to produce annual yields of rods up to 9-10 tons per acre for many years without manurial assistance except such as may be supplied in the sediments from flood water. From information which the writer has gathered as a result of association with willow growers, the sequence of yields in the life of a willow bed on good willow land, growing a general purpose variety of *Salix triandra*, may be accepted as:—

1½-2	tons	Green rods for the first year	} per acre.
2½-3	"	" " " second "	
3 -4	"	" " " third "	
4 -5	"	" " " fourth "	

increasing annually to 6-7 tons per acre for the 7th or 8th year. This yield may be maintained for the following five or six years, after which progressive decline in productivity sets in. Generally by the twentieth year reduction in yield has become so great as to render the beds no longer profitable. The practice at this stage is either to clean and replant the land with other varieties or to allow it to return to grass.

The decline in productivity of willow beds is due to one or more of the following causes:—

- Exhaustion of the soil's food supply.
- Excessive growth of weeds.
- Death of stools due to injury by insects, fungi,
use of implements and trespass by cattle.
- Neglect in attention to drainage.
- Senility of stools.

It appears reasonable to conclude that in many cases food exhaustion is the chief operating factor in causing decline, on the grounds that the heavy weight of crop (possibly amounting to 100 tons per acre in 20 years) removed as rods during the life period of

the willow plants, could not be produced without great reduction in the amount of plant food in the soil. The results obtained by chemical analysis of willow rods are given in the "Bulletin de la Société centrale forestière de Belgique, 1911" from which it may be calculated that the loss of manurial substances from the soil due to twenty successive years of willow crops would approximate to:—

Phosphoric Acid	480	} lbs. per acre.
Potassium	600	
Lime	640	
Sodium	340	
Nitrogen	1260	

The evidence that re-planted willow beds fail to give yield returns equal to those obtained from the same land when first planted from pasture, affords almost conclusive proof that so far as willows are concerned loss of soil fertility occurs.

Reliable information on the manurial requirements of the willow plant is not easy to obtain from field experiments for the reasons,

1. Wide differences in soil composition and in water content due to slight variations in level within short distances, are common. Hence, land sufficiently uniform in these respects for experimental field work is difficult to find.
2. Only such crops as are on the down grade of productiveness from lack of soil fertility are suitable for field experiments. It frequently happens that within a few years from planting beds are encumbered with weeds, variable in the number of plants present per any unit area taken, and owing to the practice of "filling in," in different years with new sets the gaps and bare patches resulting from death of the original plants, the willow crop contains plants of different ages unequally distributed. Hence, such plots as might be laid out for experiment, since they would contain different numbers of plants of varying ages, would give results not fairly comparable.
3. Flood action is variable. Sedimentation and transportation of surface soil fluctuate within short distances.

Field experiments were carried out in duplicate by the writer in 1915 at four centres in the Trent Valley on plots 1/20th of an acre in size.

The fertilisers used were:—

	Rate per acre in cwt.
Superphosphate of Lime	5
Sulphate of Potash	3
Sulphate of Ammonia	2

Time of application—January.

Results.

CENTRE A.

Plots.	Yields in lbs.	Treatment.
1	620	No Manure.
1a	735	
2	670	Superphosphates. Sulphate of Ammonia. Sulphate of Potash.
2a	725	
3	655	Superphosphates. Sulphate of Potash.
3a	640	
4	618	Superphosphates. Sulphate of Ammonia.
4a	675	
5	645	Sulphate of Potash. Sulphate of Ammonia.
5a	690	

The soil was stiff clay. The bed was six years old, fully planted and the plants were healthy. Heavy floods occurred in February and March.

CENTRE B.

Plots.	Yield in lbs.	Treatment.
1	398	No Manure.
1a	444	
2	429	Superphosphates. Sulphate of Potash. Sulphate of Ammonia
2a	444	
3	444	Superphosphates. Sulphate of Potash.
3a	475	
4	480	Superphosphates. Sulphate of Ammonia.
4a	413	
5	480	Sulphate of Potash. Sulphate of Ammonia.
5a	448	

The soil was good heavy loam. The age of the beds was about 10 years. Dead and injured plants were numerous and were irregularly distributed.

CENTRE C.

Plots.	Yield in lbs.	Treatment.
1	489	No Manure.
2	491	Superphosphates. Sulphate of Potash. Sulphate of Ammonia.
3	497	Superphosphates. Sulphate of Potash.
4	539	Superphosphates. Sulphate of Ammonia.
4	518	Sulphate of Potash. Sulphate of Ammonia.

The soil was clay warp and subject to heavy floods. The age of the bed was about 12 years. It was in fairly full plant, but the ages of the individual plants varied owing to the gaps having been filled in different years.

CENTRE D.

Neglected cultivation following application of the manures.

No record was taken of yields as the crop was spoiled by aphid attacks and dense growth of bottom weeds.

So far as yield of rods was concerned the experiments failed to give any useful information on the value of the manures used. It was observed that at the height of the growing season, the plots on which sulphate of ammonia had been used were of a darker green colour than the rest. Autumn changes and leaf fall were 10 days earlier on the plots on which sulphate of ammonia had been omitted.

The results obtained by E. W. Fenton from the application of different manures on field plots of osiers, 4 yards square, published in the Ministry of Agriculture Journal, August, 1923, show an increase in yield from the use of phosphatic, potassic and nitrogenous manures either together or separately.

Other evidence on the problem is that afforded by a few practical willow growers who have observed that applications of organic and of mixed artificial manures have given increased growth when applied to aged willow beds.

Field trials carried out in Belgium in 1910 enabled the conclusion to be drawn that the willow crop was greatly benefited by manurial treatment particularly in the cases where nitrogenous manures were applied.

The manurial requirements of the crop being imperfectly understood, it was decided to carry out investigations on the problem under pot culture conditions, because of the better control which could be secured in the elimination of the factors affecting growth in the field, in enabling detailed observations to be made during growth, in maintaining uniform treatments throughout the period of the experiment, and in accurately ascertaining yields.

Important information had been previously obtained at this Station on the manurial requirements of fruit trees by employment of the method and it was conceived that similar methods might prove successful in the case of willows.

Season 1923.

Eleven-inch plant-pots, previously waxed to reduce loss of water by evaporation, were used as containers. The medium was sand specially obtained as being lacking in available plant foods.

Seven series of plants were arranged in accordance with the nutrient treatments given. Each series consisted of three sets of each of the species, *Salix triandra*, *Salix viminalis* and *Salix purpurea*.

Series.

A. —	received	Complete	nutrient	solution.	
B. —	"	"	"	"	minus nitrogen.
C. —	"	"	"	"	" potassium.
D. —	"	"	"	"	" phosphorus
F. —	"	"	"	"	" magnesium.
E. —	"	"	"	"	" calcium.
G. —	"	"	rain	water.	

The complete nutrient solution used was :—

Sodium nitrate	0.005 %	} in distilled water.
Potassium "	0.002 %	
Calcium sulphate	0.001 %	
Magnesium "	0.001 %	
Di-potassium phosphate	0.001 %	
Sodium Chloride	0.001 %	
Ferric chloride	0.0004 %	

The other nutrient solutions were compounded by the substitution in chemical equivalent quantities of sodium for the base omitted. In the cases of omission of the essential element contained in the acid radical, the sulphate radical was substituted.

The plants were started as cuttings 11 inches in length. Three cuttings were taken in sequence from the base upwards, from each of a number of even-sized rods, washed, allowed to drain for 24 hours, and weighed immediately before planting.

Planting. The sand medium was well leached and the cuttings planted on March 17th. The tops of the pots were fitted with tarpaulin covers in order to avoid entry of rain water. The pots were placed on planks in the open air and arranged so as to show manurial series in one direction and variety series in the other.

The nutrients were given in 1 litre and $\frac{1}{2}$ litre quantities when required (as indicated by the moisture conditions of the pots), fortnightly during the earlier months and increasing in frequency to alternate days during the hot periods in June. During excessively hot dry weather water alone was used so as to avoid over-concentration of the nutrients. The pots were leached at three-week intervals by the addition of 2 litres of water to each.

Observations during Growth.

Bud break in April was fairly uniform for all plants. Differences in amounts of shoot growth, and variations in colour intensity of leaves in accordance with composition of the nutrients given, were obvious by the middle of May. In the *Triandra* series the complete nutrient plants contrasted with the rest in the longer shoots which they had made, leaves were larger and the greater

amount of "bloom" on stems and leaves indicated that they were in a most vigorous condition of growth.

The minus nitrogen and rain water fed plants of the *Purpurea* series had developed an upright habit of growth of stem in contrast with the other plants of the species where the direction of shoot growth was almost at right angles to the stem, and the growth angle of leaf and its stem was more acute.

On May 27th the number of shoots made by each set was noted and growth measurements in length of the shoots made by each plant taken.

Growth Records.

<i>Salix triandra.</i>	
	Total growth made by all shoots, in inches.
Complete Nutrient	143½
Minus Nitrogen	74
Rain Water	60½
<i>Salix viminalis.</i>	
Complete Nutrient	207
Minus Nitrogen	105
Rain Water	91
<i>Salix purpurea.</i>	
Complete nutrient.....	79½
Minus nitrogen	46
Rain Water	63

No definite differences in growth showed themselves in the case of complete nutrient, minus potassium, minus calcium and minus magnesium fed plants up to the end of June, but the minus nitrogen and rain water fed plants, and to a less degree the minus phosphorus fed plants, had failed to make the amount of growth made by the rest.

Growth measurements were taken of all plants on July 2nd.

<i>Salix triandra.</i>	
	Total growth made by all shoots in inches.
Complete Nutrient	289
Minus nitrogen	117
Rain water	119
<i>Salix viminalis.</i>	
Complete nutrient.....	343
Minus nitrogen	124
Rain water	120
<i>Salix purpurea.</i>	
Complete nutrient	217
Minus nitrogen	71
Rain water	110

No lateral shoot growth had developed in the cases of the minus nitrogen, minus phosphorus and rain water fed plants—a difference from the rest where such shoots were numerous.

At this stage it was noted from the growth figures obtained, that the heaviest sets had generally produced greatest growth,

but vigour of growth as shown by ratios of growth to weight of set was in favour of the lighter sets, i.e., the sets taken from the upper parts of the rods.

The effects of the heat wave—July 8-13—caused severe injury to many of the plants and rendered the recording of further growth measurements futile and almost impossible on account of the development of numerous basal lateral shoots. The maximum temperatures recorded on July 13th were :—

Screen	91 °F.
On tarpaulin cover	115.5 °F.
Under „ „	111-115 °F.
Sand in Pots	102-109 °F.
Soil—1 foot depth	71.3 °F.
„ 2½ „ „	64.0 °F.

The complete nutrient, minus potassium and minus magnesium fed plants of the *Salix triandra* and *Salix viminalis* series suffered most, the effects being tip and leaf scorch followed by defoliation. The minus phosphorus fed plants suffered to a less degree, while the minus nitrogen, minus calcium and rain water fed plants escaped injury. In the case of the *Salix purpurea* plants the high temperatures appeared to have had little or no effect in all nutrient series. The damage was due to the pot conditions under which the plants were being grown, because it was observed that the willow variety plots on the Station were not injured during the period. The *Salix viminalis* varieties experienced tip droop during the hottest times of the day but recovered during the following night.

In December 1923, the roots of all plants were examined. It was then found that dead black patches were present where the roots were in contact with the sides of the pots and were most numerous in the cases where greatest damage had occurred as a result of the high temperatures of July. This suggests root injury by pot contact as the cause of the death of the shoots. The minus nitrogen and rain water fed plants in July were small in shoot growth and it is probable that their roots had not then reached the pot sides. The *Salix purpurea* plants were smaller in size than the plants of the other series and their roots were probably not so extended. The minus calcium fed plants in escaping injury were remarkable since the growth which they had made was equal to that made by the complete nutrient fed plants.

Further growth made during the remainder of the growing season was mostly in the development of lateral shoots, except in the cases of the minus nitrogen, minus phosphorus and rain water fed plants of all the three species in which no lateral bud break occurred.

Fall of Leaf.

A considerable amount of leaf fall, in progressive advance from stem bases upwards, had occurred before July 2nd and was continuous in this way until the autumn. The deciduousness was least in the complete nutrient and greatest in the minus nitrogen and minus phosphorus series in all species. The differences in colour formations were associated with the differences in nutrient treatment and were constant in the cases of both early and autumn fall. The autumn tints of leaves of the complete nutrient plants were bright yellow and brown and bright colours—yellow and red-brown—characterised the minus calcium and minus magnesium fed plants. The minus phosphorus fed plants gave dull yellows and dark browns.

The crop of rods was cut and weighed in December, 1923.

WEIGHT OF CROP IN GRAMMES.

Pot No.	Series A. Full Nutrient.	B. Minus Nitro- gen.	C. Minus Potas- sium.	D. Minus Phos- phorus.	E. Minus Calcium	F. Minus Magne- sium.	G. Rain Water.
<i>Salix triandra.</i>							
1	81	11	91	36	54	60	11
2	41	10	68	29	44	68	10
3	44	7	—	28	51	70	9
<i>Salix viminalis.</i>							
4	66	9	82	53	111	79	11
5	123	12	99	33	143	84	7
6	133	10	66	25	117	88	9
<i>Salix purpurea.</i>							
7	57	5	—	33	71	55	5
8	61	6	58	28	59	44	4
9	49	6	56	23	58	47	8

The figures show,

1. The effects of withholding nitrogen from the plants are to reduce growth to an amount similar to that obtained by supplying rain water only. Hence, it follows that the other essential elements are ineffectual as growth promoters in the absence of nitrogen.
2. The effect of withholding phosphorus is to reduce growth.
3. The effects of withholding calcium or magnesium show that these elements are of less importance as growth promoters.
4. The lack of potassium did not have the adverse effects on growth expected.

Quality.

The rods produced under the several nutrient treatments were not sufficiently well grown to enable a comparison of their qualities

for basket making purposes to be made. The depth of colouring induced in the wood by boiling the rods in water showed differences, particularly in the case of the minus nitrogen and rain water fed plants. In the latter cases the "buff" was pale in contrast to the rest which were deep "red brown." A similar pale buff is produced from rods grown on peaty land

Growth commenced in March, 1924.

In the minus nitrogen, minus phosphorus and rain water fed plants the new shoot growth was retarded in the bud and weak in contrast with the plants of the other nutrient series which were vigorous.

Shoot growth during the early months followed the lines of the previous year.

Growth measurements were taken of all plants on June 4th.

	Total growth made by all shoots in inches.
<i>Salix triandra.</i>	
Complete nutrient	187
Minus phosphorus	137
Minus nitrogen ..	22
Rain water	13
<i>Salix viminalis.</i>	
Complete nutrient	444
Minus phosphorus	88
Minus nitrogen	7
Rain water	9
<i>Salix purpurea.</i>	
Complete nutrient	527
Minus phosphorus	159
Minus nitrogen	19
Rain water	17

The growth figures obtained showed,

1. Loss of vitality, reduction in number of growing points, and failure to maintain growth rates equal to plants of the other series in the cases of the minus nitrogen and rain water fed plants.
2. Check to growth in the case of the minus phosphorus fed plants.
3. Non-interference with growth rates where calcium and magnesium were absent.
4. The total shoot growth of individual plants to be in the same direction as that noted in the previous year, viz., in favour of the heavier sets.

Leaf Scorch and permanent wilt followed by death of shoot tips and defoliation amongst the *Salix viminalis* plants resulted from the temperatures experienced July 10-13, when maximums of 83°F were recorded in the screen and 65.5°F. in soil at a depth of one foot. The *Salix triandra* plants were severely leaf scorched in all

nutrient series except the minus calcium. The minus nitrogen and rain water fed plants had made little growth by July 10th. On this date the general appearance of the minus potassium, minus calcium and minus magnesium plants was similar to that of the complete nutrient plants. The minus phosphorus plants were short in growth and had produced no lateral shoots. Lateral branching had occurred in most series to such an extent as to render the taking of further growth measurements difficult.

It was noted in the middle of August that the minus magnesium plants had begun to develop dead black patches at the leaf margins. A few plants in other series except the minus calcium showed the same character in September. The localised dead patches increased in size daily and the attack progressed in acropetal order of succession of leaves. The upper 20 leaves of a marked shoot in this way had become totally blackened between August 19th and September 15th. Autumn growth of shoot of the minus magnesium plants in comparison with that of the complete nutrient and minus calcium series was, as a result of earlier loss of leaf, considerably retarded.

The progress in Black Patch development was arrested where a shoot had been dipped in the nutrient solution at 5% strength.

Fall of Leaf.

The colour changes and rate of leaf fall resembled those observed in 1923.

The crop of rods was cut in December and gave the following yields :—

WEIGHT OF CROP IN GRAMMES.

Pot No.	Series A. Complete Nutrient	B. Minus Nitrogen.	C. Minus Potassium.	D. Minus Phosphorus.	E. Minus Calcium	F. Minus Magnesium.	G. Rain Water.
1	82	0.5	<i>Salix triandra.</i>		71	58	1.0
2	10	2.2	82	20	75	56	1.2
3	97	1.0	78	16	97	57	1.8
			—	21			
4	83	1.1	<i>Salix viminalis.</i>		120	67	2.0
5	111	1.5	78	9	170	125	0.9
6	133	2.0	112	12	152	90	1.4
			72	9			
7	71	1.0	<i>Salix purpurea.</i>		92	43	0.8
8	88	1.4	—	22	70	36	0.7
9	94	1.3	76	21	95	29	1.2
			63	11			

The figures confirm the results obtained in 1923, viz. :

1. Depressing effect on growth due to lack of nitrogen.
2. Depressing effect on growth due to lack of phosphorus.
3. No obvious effects on growth due to lack of calcium.

4. Lack of magnesium is more depressing towards growth than lack of calcium.
5. The conditions of the experiment again failed to show that the absence of potassium was definitely inimical to growth.

Quality could not be determined on account of much branching which had occurred.

The buffing test gave similar results to those obtained in 1923 in the pale buff colour which was produced in the cases of the minus nitrogen and rain water fed plants.

CONCLUSIONS.

The experiment demonstrates that deficiency of nitrogen in sand medium creates conditions unfavourable to growth of the willow plant. The characters induced in the plants—short growth, upright habit of growth of stem and leaves, and poor buffing qualities—by non-nitrogenous feeding resemble those present in willow plants growing in impoverished ground. In such cases the application of nitrogenous manures could be recommended.

The value of phosphorus has been similarly shown.

As demonstrating the value of potassium the experiment failed to give information on which practical suggestions on its use as a fertiliser could be made.

The effects produced by withholding from the plant calcium or magnesium are of general scientific interest, but the bearing of these elements on field manuring as shown by the yields of rods produced cannot be considered as important.

EXPERIMENTS ON THE CONTROL OF WILLOW BEETLES.

BY A. H. LEES.

For many years the willow growing regions of Somerset have been troubled by the attack of species of *Phyllodecta* and *Galerucella*. These beetles cause extensive damage to the rods both in the larval and adult stage, large quantities of leaf tissue being devoured. The beetles frequently occur in enormous numbers and spraying has been practised for many years. Fifteen years ago when the writer was investigating the damage due to *Galerucella* sp. control was obtained by using a commercial brand of nicotine soap. At that time arsenate of lead was not favoured though no reason could be discovered for its neglect. Recently, however, the nicotine soap had apparently, in some cases at any rate, failed to give the desired result and the matter was brought to the writer's notice by the Willow Officer attached to Long Ashton.

Laboratory trials were started in the winter of 1924 in order to find some means of killing that might be applicable in the field. A supply of *Phyllodecta vitellina* was obtained and used as a test insect.

At first a good many failures were encountered. Amongst these were "red oil," paraffin and soap, paraffin and calcium caseinate, paradichlor-benzene dissolved in paraffin and made up with soap.

"Red oil" is an oil that emulsifies in dilute sodium carbonate; it has given good results in the laboratory against *Anthonomus pomorum*, the Apple Blossom Weevil, but it failed even at a 5% strength against *Phyllodecta*. Paraffin emulsified with calcium caseinate gave fair results at a 10% strength, but they were not good enough to justify more extended trials.

Nicotine Sprays.

Experiments with soap and nicotine with or without paraffin indicated that the presence of paraffin made no difference nor was a 2% soap solution superior to a 1% solution. Various strengths of nicotine were tried, 4, 6, 8, and 12 oz. per 100 gallons. From the 4 oz. strength an average kill of 30% was obtained and from the 8 oz. strength 32% kill. In one case where 12 oz. per 100 gallons was used no kill at all was obtained. The failure of nicotine was somewhat surprising but the behaviour of the beetles suggested that

recovery was due to the volatility of nicotine. only anæsthesia being produced. Accordingly nicotine sulphate was substituted for nicotine in equivalent quantities (20 oz. nicotine sulphate = 8 oz. nicotine). This mixture was much more effective and at 30 oz. to the 100 gallons a 100% kill was obtained. This formula was accordingly used later in a field trial.

Arsenate Sprays.

No information as to why arsenate spraying was not favoured by willow growers could be obtained but there was more than one possible reason. Thus :—

- (1) It might burn the foliage.
- (2) It might fail to kill.
- (3) It might kill but fresh foliage might be produced so quickly that the beetles, by starving for a short time, might escape its action.

To test (1) willow plants in pots were sprayed with arsenate up to a strength of 8 lbs. powder per 100 gallons, equivalent to a strength of 16 lbs. of paste to the 100 gallons ; no burning resulted.

To test (2) several sprayings were made using a commercial brand of powder supposed to contain some amount of "spreader" in its composition. In some cases extra "casein spreader" at .1% strength was added. Table I gives the results.

TABLE I.

Strength used in terms of powder arsenate	With extra .1% Casein Spreader.	No. of dead.	Total insects.	% kill.
4 lbs. per 100 galls.	.. No.	6	23	26
4 " " " "	.. Yes.	24	54	44
8 " " " "	.. No.	6	19	32
8 " " " "	.. Yes.	31	42	74

The beetles were very hungry but very chary of feeding on arsenated foliage. Where no spreader was used and the arsenate was in patches the beetles fed in between. Where a spreader was used very little foliage was eaten but that small amount was sufficient to cause a considerable mortality. The influence of the spreader and increased strength are clearly to be seen in the tabulated results and it is thus evident that a very effective cover must be obtained before the beetles are forced to take the poison. The 8 lbs. per 100 gallons strength was used later in a field trial.

Arsenate Dusts.

If a dust could be used instead of a spray much labour could be saved. Accordingly a 10% and 20% arsenate powder lime dust

were tried. Both were about equally effective but neither so much as the liquid form.

The first formula was subsequently used in the field trial.

Field Trials.

These were done on small plots on a plantation in Mid-Somerset. Reference is made to them in the Advisory section of the Report by the Willow Officer.

The treatments were as follows :—

- (1) Dusting with arsenate-powder-lime dust (10% arsenate, 90% lime).
- (2) Spraying with arsenate powder and casein spreader (arsenate 8 lbs. powder, casein spreader .1%, water 100 gallons).
- (3) Spraying with nicotine sulphate and soap (nicotine sulphate 30 oz. soap 1%, water 100 gallons).

Rain interrupted operations at the first application on June 20th, but four days later the complete series was repeated under conditions of fine weather.

The experiment was revisited six weeks later in August after a large amount of rain had fallen.

On the controls very little beetle damage had occurred so it was not possible to estimate the efficacy of the treatments as insecticides.

The arsenate powder and spreader spray had, however, adhered very well indeed and is evidently almost proof against rain after it is once dry.

The dust had remained fairly well also but probably not sufficiently well to prove effective.

No certain information could be gathered from the result of the nicotine sulphate spray though there was a distinct suggestion that other pests had been controlled to some extent.

In view of the promising results obtained it is hoped to repeat these experiments this season.

REPORT ON ADVISORY WORK, 1923-24.

During the year the scope of the advisory work carried out at this centre has been further extended by the appointment of Dr. J. A. Hanley as Agricultural Information Officer. He now serves as Chief Advisory Officer. A preliminary report on his work is included.

By the appointment of an Adviser in Mycology it has also been possible to deal more thoroughly than hitherto with advisory problems in this subject. Although the officer only took up his duties on February 18th, it will be seen from his report that since that time he has been very fully occupied in the province.

There is a further small increase over previous years in the number of enquiries received and there is every reason to believe that the work of the centre will be maintained in future years.

The Advisory officers have worked very closely in conjunction with the various County Organisers of the Province during the year and many experiments are being carried out jointly by the Advisory Centre and the various County Authorities.

The statistics of enquiries for the past five years are given in the following table, which shows also the numbers received from each of the counties comprising the Bristol Province.

						Year ending Sept. 30th.				
						1920	1921	1922	1923	1924
Gloucester (including Bristol) ..	..	..	..	..	..	53	73	78	136	137
Hereford ..	..	..	..	..	..	10	22	21	62	107
Somerset ..	..	..	..	..	..	79	96	114	141	130
Wiltshire ..	..	..	..	..	..	3	10	18	66	24
Worcester ..	..	..	..	..	..	29	45	46	48	78
Other Areas ..	..	..	..	..	..	117	125	201	205	195
						291	371	478	658	671

Included in the figures under " other areas " are enquiries received from Devon and Monmouth, both of which counties contribute annual grants to the Long Ashton Institute, although not forming part of the Bristol Province.

The figures given have reference only to enquiries dealt with by correspondence. Much advisory work is not recorded by them, since a large amount of advice is given to farmers and growers visiting the Station or on the occasions when advisory officers visit farms in the course of making tours of various areas in the Province.

As regards the subjects of enquiry, these show a steady increase under all heads with the exception of fruit products, which shows a decrease. Actually there has not been any marked decrease in the advisory activities under this latter head, as might be suggested by the figures for the past two years, as in this department much verbal advice is given, enquirers often preferring to visit the Station to talk over matters with the officer rather than deal with certain aspects of the work by letter. In addition most of the enquiries in this subject other than those relating to cider making are now dealt with by the Campden Station, the work of which is not included in this Report.

The reports of the Advisers in Economic Mycology and Economic Entomology still indicate that farmers do not utilise the advisory facilities provided in these subjects by the Advisory Scheme to as great advantage as they might do. Such advice is, however, eagerly sought after by fruit growers.

The enquiries relating to willows and to fruit and vegetable preservation are not included in the above statistics.

A separate report on the former work by the advisory officer in that subject is appended, while the latter are dealt with in the report of the Campden Station.

NATURE OF ENQUIRIES.

Fruit Products (including Cider-Making.)

The enquiries received through the post, viz., 152, represent only a portion of the work dealt with under this head. The most important part has been covered in the course of personal interviews at the Research Station and visits to orchards and cider-making premises, on which occasions there has frequently been opportunity for practical demonstrations touching upon the points of enquiry. The written enquiries were distributed as follows :—

Gloucester	..	..	..	..	..	..	24
Hereford..	..	..	..	..	..	..	14
Somerset..	..	..	..	..	..	..	29
Wiltshire..	..	..	..	..	..	..	1
Worcester	..	..	..	..	..	..	9
Other Areas	..	..	..	..	..	..	75

152

Included in the above are several enquiries received from the following countries outside Great Britain :—Ireland, Canada, East Africa, South Africa, New Zealand, France and Denmark.

The questions raised cover practically the whole field of cider and perry making. They have referred to the characters of cider fruit, vintage varieties recommended for propagation; cider orchards, cider-making appliances, equipment and methods of manufacture; the storage, preservation and bottling of the finished

product ; its composition ; various bacterial and other disorders ; the action of various preservatives ; and by-products, such as cider vinegar and dried pomace. Among particular subjects treated there may be mentioned the establishment, equipment and general working methods of a cider factory, the financial aspect of cider-making, the use of culinary and dessert varieties of apples for vintage purposes, the characters of French cider varieties and French ciders, the physiological effects of cider, and the action of that beverage on metals.

Other matters under this head which have been dealt with are the production of concentrated fruit juices and methods of clearing extracts of apple pulp and fruit juices.

Pomological.

The 91 written enquiries under this head originated as follows :—

Gloucester	..	..	..	..	..	..	18
Hereford..	..	..	..	..	..	..	5
Somerset..	..	..	..	..	..	..	12
Wiltshire..	..	..	..	..	..	..	0
Worcester	..	..	..	..	..	..	14
Other Areas	..	..	..	..	..	..	42

91

As in all other sections of the advisory work, the figures give an inadequate idea of the total amount actually dealt with, so much being done by personal interviews with visitors to the Station and growers on their own farms. They also relate only to enquiries which are primarily pomological in character ; the numerous cases concerned with definitely pathological aspects of fruit culture are included in the mycological and entomological sections of this Report.

Few, if any, of the questions involved presented novel features or call for special comment. A relatively large number related to strawberry culture and their nature clearly indicated the pressing need for investigations on "red plant" and other abnormal and possibly related forms of growth which are now being undertaken at the Station. The other conspicuous feature among the enquiries has been the frequency of cases largely attributable to bad weather conditions during the growing season, such as failure of blossoming trees to produce crops.

The following five sections, dealing with Agricultural Chemistry, Economic Entomology, Economic Mycology, Agriculture and Willow Culture, have been respectively contributed by Mr. T. Wallace, Mr. L. N. Staniland, Mr. R. M. Nattrass, Dr. J. A. Hanley and Mr. H. P. Hutchinson, the Advisers in those subjects.

AGRICULTURAL CHEMISTRY.

The number of requests for advice received during the year was 173. The sources and nature of these enquiries, together with their special points of interest, are given below :—

SOURCES OF ENQUIRIES.

Gloucester	..	..	..	..	..	43
Hereford..	..	..	..	..	..	58
Somerset..	..	..	..	..	..	41
Wiltshire..	..	..	..	..	..	7
Worcester	..	..	..	..	..	13
Other Areas	..	..	..	..	..	11

Total	..	..	..	..	..	173
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NATURE OF ENQUIRIES.

(1) *Soil Problems.*(a) *Soil Manurial Problems.*

Pastures and Meadows	..	..	..	..	..	43
Arable Soils	..	..	..	..	..	160
Fruit Soils	..	..	..	..	..	20
Hopyard Soils	..	..	..	..	..	10
Market Garden and Nursery Soils	..	..	..	..	..	2
Garden Soils	..	..	..	..	..	3

Total	..	..	..	..	..	238
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(b) *Miscellaneous Soil Problems.*

Soil Conditions causing Chlorosis of Fruit Trees	..	7
" " in cases of Leaf Scorch of Fruit Trees	..	13
" " " failures of Fruit Crops	..	9
" " " failures of Hops	..	3
" " " failures of Agricultural Crops	..	26
Suitability of Soils for Fruit Growing	..	11
" " Cucumber Growing	..	1

Total	..	..	..	..	..	70
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(2) *Miscellaneous Enquiries.*

Agricultural value of samples of Lime Materials	..	9
Potash content of samples of Wood Ashes	..	1
Manurial value of sample of Town Refuse Manure	..	1
" " " Glassworks Refuse	..	1
" " " Sewage Sludge	..	2
" " " Waste Bone material	..	1
" " " liquid effluent from waste fruit heap	..	1
" " " Leather waste	..	1
" " " "Grass" manure	..	1
" " " "Hop" manure	..	1
" " " treated Soda Ash	..	1
" " " Soot	..	1
" " of samples of Fertiliser damaged by floods	..	2
General enquiries on Manuring of Fruit Trees	..	5
" " " Agricultural Crops	..	3
Fineness of grinding of samples of Basic Slag	..	1
The mixing of various Fertilisers	..	1
Composition of samples of Lawn Sand	..	1
The use of potash manures against Leaf Scorch	..	1
Manurial treatment against "Stripe" in Tomatoes	..	1
Analyses of samples of Feeding Stuffs	..	2

Total	..	..	..	..	..	38
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Number of Samples examined in dealing with Enquiries.

Soils	323
Lime materials .. .	9
Miscellaneous samples .. .	29

Total .. .	361
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Number of farms visited in dealing with Enquiries 54

OBSERVATIONS ON ENQUIRIES.

The number of enquiries submitted to the Department showed a further increase over that of last year. The proportion of the enquiries received from the several counties of the Province was fairly similar to that of last year with the exceptions that there was a large increase in number from Herefordshire and a large decrease from Wiltshire. The large increase in numbers from Herefordshire was to a great extent due to the fact that the Agricultural Organiser has encouraged farmers in that county to submit soil samples for examination from fields in which he suspected poor cropping to be due to acid conditions, whilst the fall in the number from Wiltshire was due to the fact that the number received in the previous year was abnormally high owing to many of the samples examined during that year having been submitted as the result of a special campaign which was conducted in parts of the county by the County Organiser on the subject of "the liming of Greensand soils."

With regard to the nature of the enquiries dealt with, it will be noted from the figures given that these related almost wholly to soil problems and fertilisers.

(1) *Soil Enquiries.*

The general nature of the soil enquiries was similar to that of previous years. The largest proportion of these related to the cropping of arable soils and in the majority of such cases it was found that where difficulties in cropping were experienced the soils were deficient in lime.

The more interesting cases of this type of enquiry were those from the Bunter Sandstone districts in Gloucestershire and Worcestershire where, owing to the wet nature of the season preventing the working of root crops in the early stages, spurrey grew so vigorously that it completely smothered the young plants.

Some liming trials are being arranged on some of the worst fields examined in these areas.

A number of instances of soil acidity associated with poor cropping on some of the deeper Oolite soils on the Cotswold Hills were investigated during the season. Such examples are of importance as acid soil conditions are not generally suspected on these soils.

Other important cases examined were in connection with poor cropping on heavy calcareous soils derived from the Lower Lias formation, on brashy Oolite soils and on intractable clays from the Fullers' Earth formation.

Enquiries submitted on the subject of pasture improvement generally related to the desirability of using various forms of phosphatic fertilisers for this purpose. An interesting case was observed at Sevenhampton, Gloucestershire, on a meadow, the soil of which was a heavy Lias clay in which the herbage was in very poor condition, which showed no improvement from phosphatic manuring, but which responded markedly to a dressing of kainit. The meadow had previously been "hayed" for many years.

Many of the enquiries relating to Fruit Soils have provided matter for detailed investigation and some of the problems which they raised will be investigated during the course of the next season or so.

Further cases of "Leaf Scorch" and Chlorosis of fruit trees were examined and these have furnished useful data for investigations on these problems now in progress at this Research Station.

Three cases of failures of hops were reported from Hereford and in two of these cases the failures were found to be due to "hard pan" and one to the peculiar close textured silty nature of the soil. The roots of the hops in the former two cases were waterlogged during the period of heavy rains and the foliage during the whole of the season remained yellow.

(2) *Miscellaneous Enquiries.*

There were no special points of interest in connection with these enquiries.

SPECIAL INVESTIGATIONS IN PROGRESS DURING THE SEASON.

(1) *Field Experiments on "The Eradication of Bracken from Poor Moorland Pastures."*

These experiments were continued in conjunction with the Experiments Committee of the Bath and West and Southern Counties Agricultural Society.

(2) *Field Experiments on "The Improvement of Poor Pastures where the Soils are Acid in Reaction."*

Experiments were laid down at nine centres in the Province. At these centres various phosphatic fertilisers and lime are being tested,—in conjunction with the Experiments Committee of the Bath and West and Southern Counties Agricultural Society.

(3) *Field Experiments as under on "The Manuring of Fruit Trees in Plantations and Grass Orchards."*

- (a) Effect of dung and potash manures on Leaf Scorch (experiments continued)—in conjunction with the County

Organiser for Worcester, the Horticultural Superintendent for Somerset, the Horticultural Instructor for Hereford and various fruit growers.

- (b) The effect of phosphatic manures in a case where deficiency in phosphoric acid is indicated (experiments continued)—in conjunction with the Agricultural Organiser for Worcestershire.
- (c) The effect of autumn and spring dressings of nitrogen on apple trees (experiments continued)—in conjunction with County Organiser for Worcestershire.
- (d) The effect of dressings of phosphatic and potassic manures on apple trees in grass orchards (experiments continued)—in conjunction with Agricultural Organiser for Gloucestershire.

(4) *Field Experiments on "The Effect of Spraying with Sulphate of Iron on Chlorosis of Apple Trees."*

These experiments were continued in conjunction with the Horticultural Superintendent for Somerset.

(5) *Experiments on "Liming of Arable Soils."*

These experiments were continued under the scheme of the Ministry of Agriculture and Fisheries.

Centres where experiments are in progress :—

Hereford	..	..	..	..	..	..	4 centres
Gloucester	..	..	..	..	..	..	1 centre
Worcester	..	..	..	..	..	..	1 „

Further centres were selected for experiments under this scheme as under :—

Gloucester	..	..	..	..	..	..	2 centres
Worcester	..	..	..	..	..	..	1 centre

(6) *Survey of Fruit Soils on the Old Red Sandstone Formation in the West Midlands.*

Continued—under the Scheme of the Ministry of Agriculture and Fisheries.

Work was continued in the laboratory on the soil samples collected from the areas under survey.

ECONOMIC ENTOMOLOGY.

Though the report here given is for the whole year, the present Advisory Entomologist only took up his duties on May 9th, 1924.

The number of letters of enquiry dealt with during the year was 113, of which only four were of an agricultural nature, the

remainder all dealing with fruit. The enquiries dealt with were as follows :—

Gloucester (including Bristol)...	18
Hereford	14
Somerset	14
Wiltshire	4
Worcester	24
Other Counties	39
Total	113

This number shows an increase of 33 enquiries on last year. Of the total number of enquiries, 25 were dealt with by the present Adviser, the remainder receiving attention prior to his appointment.

In addition to advice sent by letter, in answer to enquiries, much information has been given in connection with 64 advisory visits made during the year by the present Adviser. In addition to these a number of visits were made by the other Advisers earlier in the year.

The following is a list of the pests, classified under host plants, which have been serious during the period under review.

Host Plants.	Pests.	Remarks.
Apple	Capsid bugs (<i>Plesiocoris rugicollis</i>)	Fairly general, but particularly in Gloucester, Hereford and Worcester
"	Apple Sawfly (<i>Hoplocampa testudinea</i>)	
"	Caterpillars, including Winter Moth, Tortrix larvae, etc.	Serious in places but unevenly distributed
"	Apple Blossom Weevil (<i>Anthonomus pomorum</i>)	In some cases up to 80% of the blossom was "capped"
Plum	Plum Aphis (<i>Anuraphis pruni</i>)	
"	Plum Sawfly (<i>Hoplocampa fulvicornis</i>)	Bad in the Evesham district and in parts of Hereford and Gloucester
Black Currant	Capsid bugs (<i>Psallus sp.</i>)	Some bad cases in Evesham dist.
"	Aphids	
Raspberry and Loganberry	Logan Beetle (<i>Byturus tomentosus</i>)	Particularly in Evesham district
Gooseberry	Gooseberry Sawfly	
Strawberry	Eelworm attacks	"Cauliflower" in Hereford. "Red Plant" general. "Patch" at Evesham and Long Ashton
Mangold	Mangold fly (<i>Pegomyia betæ</i>)	Severe in Somerset
"	Slugs	Severe in Wiltshire

The advisory letters sent during the year have dealt principally with the following questions, in addition to the list set out above :—

Host Plants.	Pests.
Apple	Wood Leopard Moth (<i>Zeuzeura pyrina</i>)
	Ichneumon cocoons
	November Moth (<i>Oporabia dilutata</i>)
Apple and Pear ..	Apple and Pear Leaf Blister Moth (<i>Ornix petiolella</i>)
	Caterpillars of various kinds.

Host Plants.	Pests.
Cherry	Sawfly (unidentified)
Plum	Mites (<i>Oribata lapidaria</i>) (beneficial)
Vine	Mealy Bugs
Walnut	Leaf Gall Mite (<i>Eriophyes tristriatus</i> , var. <i>erineus</i>)
Strawberry ..	White Fly
	Leaf Hoppers
Oak	Spangle Galls (caused by <i>Neuroterus baccarum</i>)
Raspberry ..	Sawflies (unidentified)
Tomatoes ..	Leaf Hoppers
Teazel	Aphids (<i>Macrosiphum rosae</i>)
"Cudweed" ..	An enquiry as to whether an aphid (<i>Pemphigus</i> sp.) present was Woolly Aphid or not.

Much advice has been given concerning winter egg-killing washes, particularly the Carbolineum fluids, and in connection with black currant pests.

INVESTIGATIONS IN PROGRESS.

Work is being carried out in collaboration with the Research Entomologist, on the "Red Plant" disease of strawberries. An investigation is also being pursued in connection with a fly doing damage to Teazels in Somerset. A field experiment was carried out, by kind permission of a grower in the Evesham district, in order to test the effect of a reduction of the number of sprayings with Lead Arsenate against the Logan Beetle (*Byturus tomentosus*). Bad weather conditions made the carrying out of the experiment difficult and doubtless caused the spraying to be less effective than it might have been. Arsenate paste was tried against Arsenate powder and the latter was found to be the more effective. A casein spreader was used in each case. A difference of 4% only in favour of the treated bushes was found between the untreated control and the area sprayed with arsenate powder; this difference was found by counting the number of berries in equal weights from the two areas.

ECONOMIC MYCOLOGY.

Prior to the present Adviser taking up duty on February 18th, 20 enquiries had been received by the Mycological Department. These enquiries were dealt with by the Research Mycologist.

Sources of Enquiries.

The total number of enquiries dealt with during the past year and their sources are given below:—

Gloucester	34
Hereford—	16
Somerset	34
Wiltshire	12
Worcester	18
Other Counties ..	28
Total	142
Visits paid to farmers and growers during the period under review	88

General Observations on Enquiries.

The season has been notable for the epidemic occurrence of several diseases—in part due to its abnormally wet character. Of these the more important were as under:

(1) *Chocolate Spot*. One of the earliest of these outbreaks was that of Chocolate Spot of field beans. Enquiries were received from each of the five counties, particularly severe cases being reported from the Severn Valley.

A series of field trials and pot experiments are being carried out in collaboration with the Agricultural Organiser for Gloucester, the object being to test the value of potash dressings and seed sterilization, and also to ascertain to what extent the disease is carried on in the soil.

(2) *Ring Spot of Lettuce*. The Ring Spot Disease of lettuce (*Marssonina panattoniana*), a hitherto comparatively uncommon disease in this country, appeared fairly extensively in Gloucestershire and Wiltshire.

(3) *Black Scab*. The Black Scab of apples and pears (*Venturia inaequalis* and *pirina*) was very prevalent. It was the worst attack for many years.

(4) *Potato Blight*. The potato Blight (*Phytophthora infestans*) was widespread and serious throughout the province, particularly in Somerset.

(5) *Currant Leaf Spot*. An epidemic attack of the Currant Leaf Spot (*Pseudopeziza ribis*) occurred on nearly all plantations of black currants. The attack was followed in many cases by the Currant Rust (*Cronartium ribicola*). The two diseases were frequently confused—damage done by the former being attributed to the latter.

(6) *Plum Diseases*. Many enquiries were received dealing with diseases of plum trees.

(a) *Silver Leaf*. There is evidence that "Silver Leaf" is on the increase, particularly among Victorias. A few cases have been noted on Egg Plums. Some growers are attempting to control the disease by the practice of "ringing" and by the use of proprietary articles such as "Silver Stop," but so far no conclusive results have been obtained.

(b) "*Die-Back*." The "Die-Back" of stone fruits caused by *Diaporthe perniciosa* has resulted in the loss of many trees in the five counties. Observations made bear out the point, which is being emphasised by the Research Mycologist in work shortly to be published, that the

invasion by *Diaporthe perniciosa* follows some serious physiological disturbance brought about by unsuitable conditions, such as bad drainage, injury to roots and stem by implements, and indiscriminate and bad pruning. Pruning snags and chafing wounds by the stake form a ready means of entry to the fungus. Prevention of these two, in addition to keeping the tree as strong and healthy as possible, is indicated as being the means of controlling the disease.

- (c) *Leaf "Shot-Hole."* A disease causing leaf "shot-holes" and lesions on the stems of young nursery plum stock was sent in for diagnosis. An unidentified bacterial organism was found to be associated with, and is probably the cause of, the disease.

(7) *Fruit Rot of Pears.* A fruit rot of pears was submitted for diagnosis. The fungus isolated is being investigated in collaboration with the Research Mycologist.

List of Subjects of Enquiry.

The following list indicates the nature of the majority of the enquiries received during the year:—

Host Plant.	Nature of Disease.	Causal Organism.
APPLE	Black Scab	<i>Venturia inaequalis</i>
	Canker	<i>Nectria galligena</i>
	Mildew	<i>Podosphaera leucotricha</i>
PEAR	Leaf Spot	Physiological (?)
	Black Scab	<i>Venturia pirina</i>
	Rust	<i>Gymnosporangium sabinae</i>
PLUM.. ..	Silver Leaf	<i>Stereum purpureum</i>
	"Die-Back"	<i>Diaporthe perniciosa</i>
	Root Rot	<i>Armillaria mellea</i>
	Wither Tip	<i>Monilia cinerea</i>
PEACH	Brown Rot	<i>Monilia fructigena</i>
	Leaf Curl	<i>Eoascus deformans</i>
	"Die-Back" and Fruit Rot ..	<i>Diaporthe perniciosa</i>
CHERRY	Wither Tip	<i>Monilia cinerea</i>
GOOSEBERRY ..	American Gooseberry Mildew	<i>Sphaerotheca mors-uae</i>
BLACK CURRANT ..	Leaf Spot	<i>Pseudopeziza ribis</i>
	Rust	<i>Cronartium ribicola</i>
	Silver Leaf	<i>Stereum purpureum</i>
MANGOLD	Violet Root Rot	<i>Rhizoctonia violacea</i>
BEAN	Chocolate Spot	<i>Bacillus lathyri</i>
PEA	Root Rot	<i>Thielavia basicola</i>
WHEAT	"Take all"	<i>Ophiobolus graminis</i>
POTATO	Late Blight	<i>Phytophthora infestans</i>
	Dry Rot	<i>Fusarium caeruleum</i>
CLOVER	"Sickness"	<i>Sclerotinia trifoliorum</i>
LUCERNE	Leaf Spot	<i>Pseudopeziza medicaginis</i>
CELERY	Leaf Spot	<i>Septoria apii</i>
LETTUCE	"Ring Spot"	<i>Marssonina panattoniana</i>
ONION	White Rot	<i>Sclerotium cepivorum</i>
	Mildew	<i>Peronospora Schleideni</i>
SALSIFY	White Rust	<i>Cystopus tragopogonis</i>
TOMATO	Canker	<i>Diplodina lycopersici</i>
	Stripe	<i>Bacillus lathyri</i>
	Stem disease	<i>Sclerotinia sp.</i>

AGRICULTURE.

This section of the Advisory work began with the establishment of the Bristol Centre in April, 1924.

Since then the Adviser has been almost fully occupied with grassland work for the Ministry and it has not been possible, therefore, to develop advisory work in the Bristol Province extensively yet.

A certain amount of work has been carried out in the Province, chiefly in connection with problems relating to temporary and permanent grassland.

One interesting innovation in county work on agricultural education in Herefordshire should be mentioned in this connection. The Agricultural Adviser was called in, together with a prominent farmer of the district, to judge grassland recently laid down, and from their experiences to draw up a judges' report for the guidance not merely of future competitors, but also of any farmer who contemplates laying down land to grass. There were thirty entries and the prominence given to this competition will undoubtedly draw the attention of many farmers to the value of adopting suitable seeds mixture and good methods of cultivation, etc., when sowing land down to grass. Advice has also been given on Down land in Wiltshire and on grassland in Somerset and Gloucestershire.

WILLOW CULTURE AND THE UTILIZATION OF WILLOWS.

The total number of enquiries answered by letter during the year was 92, distributed as follows :—

Gloucester	..	..	..	..	..	..	12
Hereford..	..	..	..	..	..	..	0
Somerset..	..	..	..	..	..	..	9
Wiltshire..	..	..	..	..	..	..	0
Worcester	..	..	..	..	..	..	4
Other Areas	..	..	..	..	..	..	67
Total	..	..	..	..	..	..	92

As in previous years the enquiries were mostly concerned with :—

- (1) Suitability of different types of land for the Basket willow crop and the cultivation of willow varieties for different basket-making purposes.
- (2) Method of preparing land for the crop.
- (3) The planting of Tree Willows, chiefly the Cricket-bat Willow.

Special advice was given to prospective willow growers in Canada, Natal, Australia, New Zealand, Tasmania and India. A consignment of willow sets comprising twenty-two varieties was despatched at the request of the Department of Agriculture for New Zealand for trial experiments in that country. Similar consignments of

sets were sent to settlers in New Zealand and to a native willow grower in Kashmir, India.

Insect and Fungus Pests.

The summer of 1924 proved favourable to the growth of the willow crop and damage due to insect and fungus attacks has been less than in previous years.

Field experiments on the control of Beetle attacks were devised and carried out in Somerset in collaboration with Mr. A. H. Lees, Entomologist at this Station, but no results of economic value were obtained owing to the crops being only slightly attacked.

A Lancashire willow grower reported a severe attack of *Phylospora gregaria* on the varieties "Violets" and "Mawdsleys." Specimens were sent to Dr. G. H. Pethybridge, Pathological Laboratory, Harpenden, for fuller investigation.

Cricket-Bat Willow Culture.

Twelve enquiries were received. The advice given was in connection with:—

Methods of production of sets suitable for planting as trees.

Suitability of land and the obtaining of sets.

The growing of Cricket-bat willows under sewage farm conditions. A case was brought to the notice of the Adviser where 50 Cricket-bat trees, growing on a sewage farm in Somerset, had been sold for £550. The age of these trees was 20 years from the time of planting.

Land Inspection.

Four inspections of land for willow culture were made in Somerset, Pembroke and Worcester, and advice given on drainage, planting and general management of the willow crop.

Exhibits.

Exhibits of willows and willow products were shown at the Bath and West and Southern Counties Show, at Taunton, and at the British Empire Exhibition, Wembley.

The exhibit at Taunton consisted of growing plants of the chief commercial varieties of willows, dyed willow rods, and rods buffed by a new method.

The uses which might be made of willow bark were demonstrated.

Many enquiries were answered during the Show week.

A public address on "The Value of the Willow as a Means of Utilising Wet Land" was given at the Bath and West and Southern Counties Show, Taunton, and an article entitled "The Buffing of Willows" was published in the Journal of the Bath and West and Southern Counties Society.

